Special Section: Treasures of the Air and Space Museum

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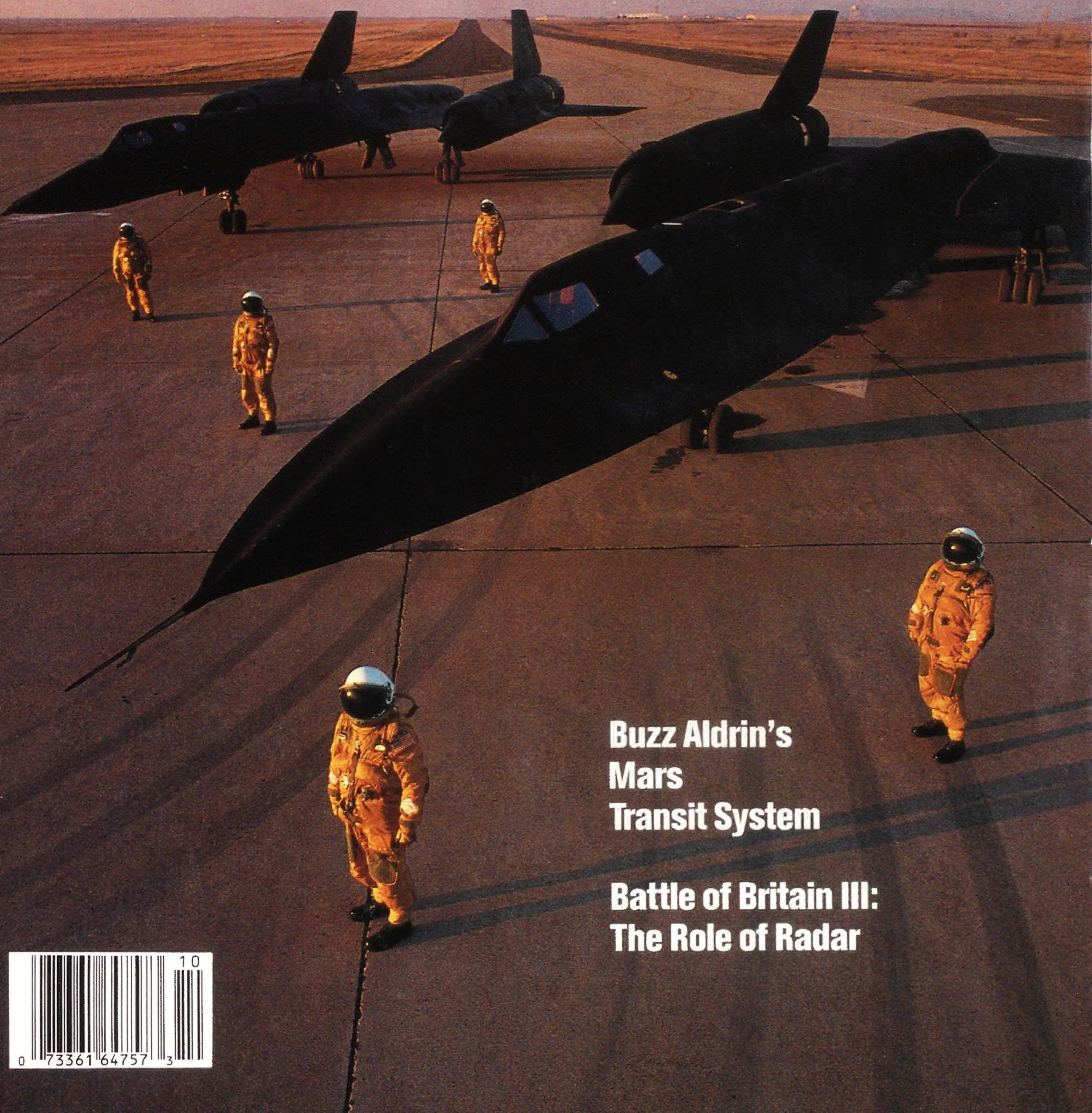
Smithsonian • October/November 1990

HOW THE BUDGET KILLED THE BLACKBIRD



Buzz Aldrin's Mars Transit System

Battle of Britain III: The Role of Radar

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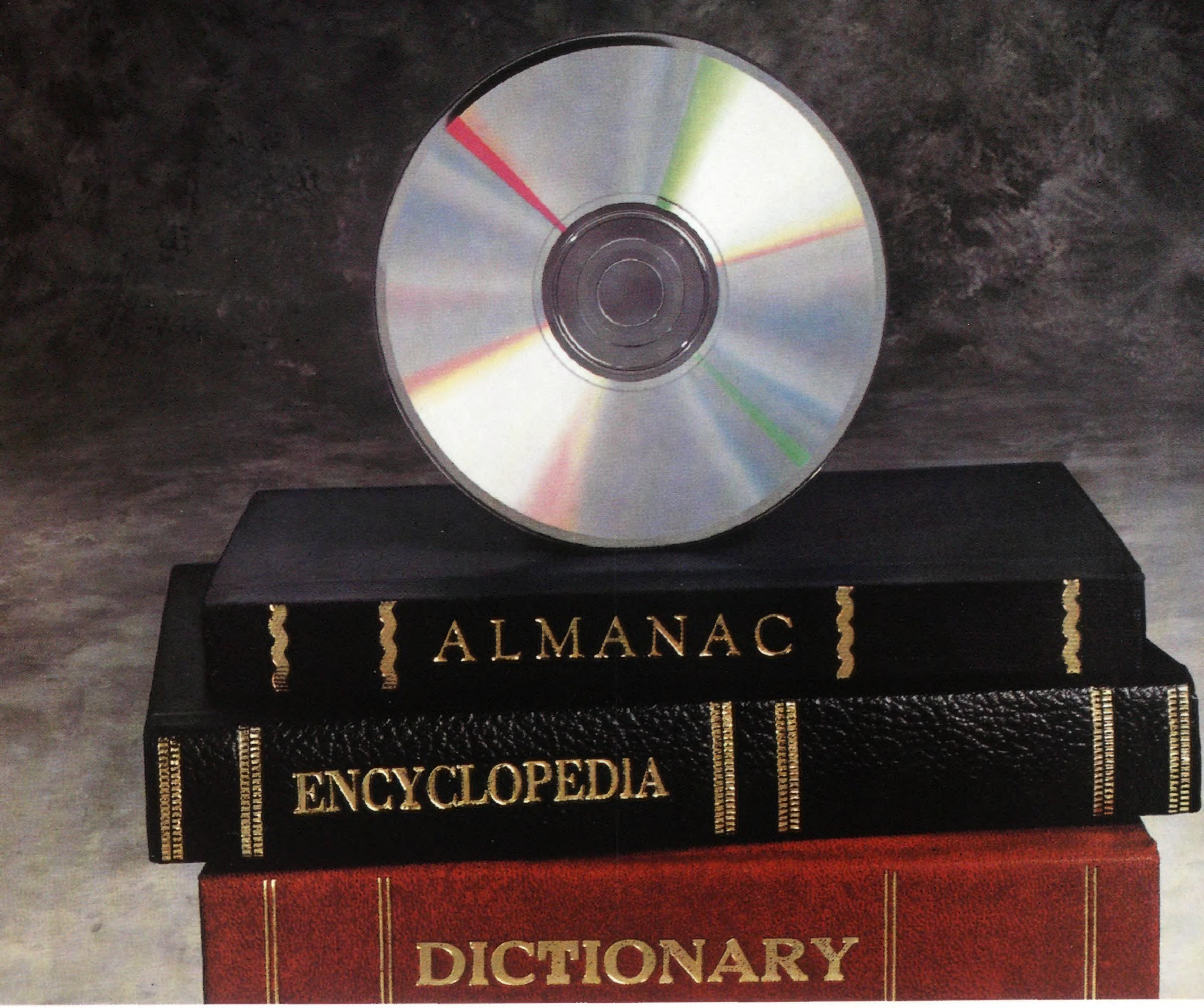
The Miracle.



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Viewport

Billion-Dollar Space Instruments

In August 1989, the European Space Agency launched its Hipparcos observatory. It had cost several hundred million dollars and was to pinpoint the locations of stars to accuracies never achieved before. When it failed to reach its designated orbit, considerable concern was voiced all over Europe. But scientists went to work to figure out their fallback options, and a year later the data streaming in from the telescope, still in its limited orbit, indicates that virtually all the results that had been hoped for will be obtained.

This spring, when the long-heralded Hubble Space Telescope went into space only to reveal a crippling inability to properly focus light, Congress called hearings, NASA set up a special investigative panel, and newspapers published critical editorials and derisive cartoons.

NASA scientists and engineers, meanwhile, were checking the symptoms step by step and determined the trouble to lie with the 94-inch primary mirror, designed to gather light from distant galaxies to produce the sharpest astronomical images ever obtained. This mirror had been figured more accurately than any astronomical optic constructed before—though, as the tests began to show, to slightly wrong specifications. The mistake produced spherical aberration, a defect that the installation of relatively simple correcting mirrors fortunately can cure. That's a relief, because NASA had already been planning to send astronauts up to the telescope to replace at least some of its instrument packages within a few years. These visits may provide an opportunity to take aloft a new set of instruments in which the needed corrective optics have been installed.

In the meantime, not all of the instruments currently mounted on the telescope are equally affected by the aberration. The two spectrographs, which analyze visible and ultraviolet radiation to determine the chemistry, temperature, and other physical properties of stars and galaxies, still can be used effectively, as can the high-speed photometer, an instrument designed to sense rapid variations in the light radiated by stars (see "First Light for the Hubble," April/May 1990). Astronomers' requests to use these instruments had at first outstripped the time allocations. Now, there may be an opportunity to emphasize observations with these particular instruments first, while steps are taken to replace other instruments more severely affected.

As we look at the cost and implications of space projects of the future, we realize that putting payloads into orbit is only worthwhile if the cost of the launch itself is small compared to the cost of the entire mission. And as long as launch costs alone for large payloads lie in the hundred-million-dollar range, we will continue to see billion-dollar missions.

That makes economic sense, but expenditures in that price range require packing as much as we possibly can into each successive payload. And, as with any devices that go well beyond past technological achievements, there will always be occasional failures—even with billion-dollar projects.

Since taxpayer money is involved, billion-dollar failures must be a cause for alarm. But we should recognize that unanticipated problems may sometimes be an unavoidable feature of ambitious missions. The reality is that cost drastically escalates with demand for unrealistically high reliability. Reducing the risk of failure to absolute zero would make the testing required for a complex mission impossibly expensive. Risking a setback from which we have a chance to recover sometimes makes far better financial sense.

While expensive failures are always hard to accept, they become tolerable when engineers and scientists rally, with the kind of resilience and dedication we are now seeing at NASA, to find ways of correcting mistakes and ensuring that original goals for the mission are still met.

Perhaps that is as much as we have a right to expect.

—Martin Harwit is the director of the National Air and Space Museum.

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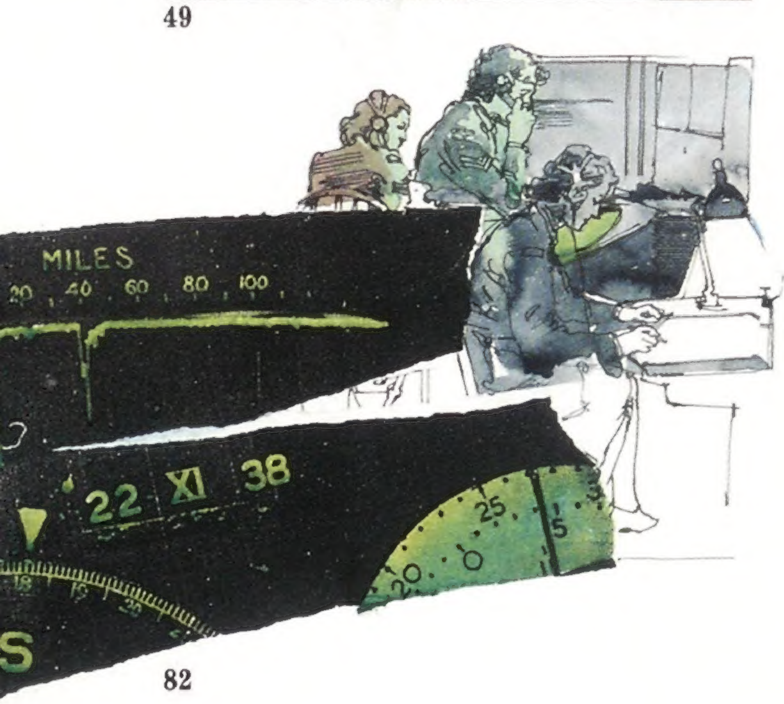

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Cover: A pair of Blackbirds await their pressure-suited crews in this photograph by Eric Shulzinger.

Departments

AIR & SPACE/Smithsonian (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. Subscription price: $18 a year in U.S. possessions, $24 elsewhere. Eighty-five percent of dues is designated for magazine subscription. Single-copy price: $3.50. Second-class postage paid at Washington, DC, and additional entry points. Editorial offices: 370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Advertising and circulation offices: 420 Lexington Ave., New York, NY 10170. Members: Address all subscription correspondence and change-of-address information to P.O. Box 53261, Boulder, CO 80322-3261. Postmaster: Send address changes to *AIR & SPACE/Smithsonian,* P.O. Box 53261, Boulder, CO 80301-3261.

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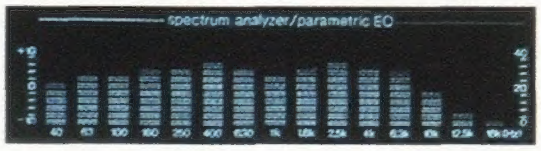

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Letters

The Unanswered Question

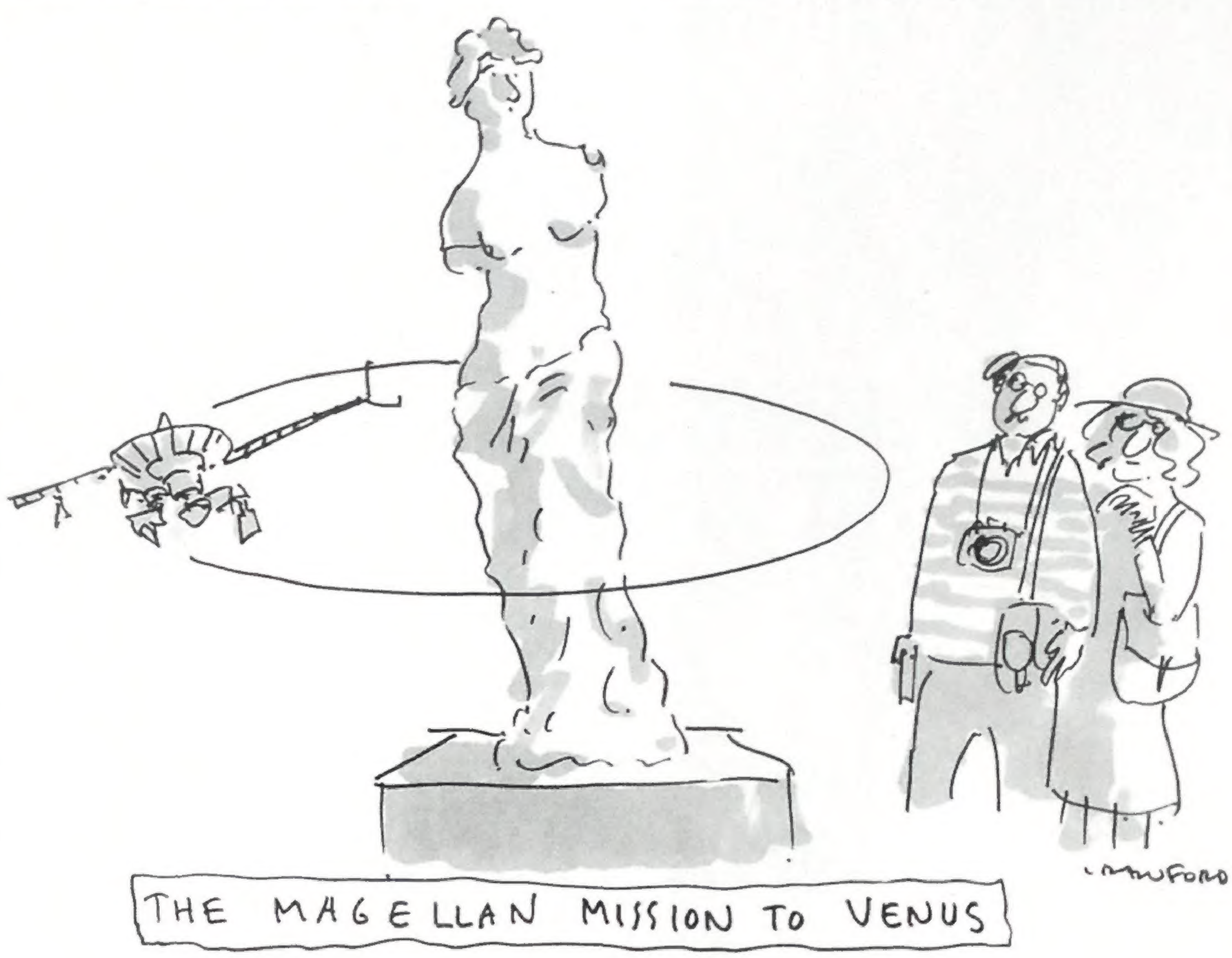
Wayne Biddle's article "Two Faces of Catastrophe" (August/September 1990) was excellent and had a good perspective. However, it left at least one question unanswered. Since Mr. Webb and Dr. Seamans did not directly influence the conclusions in the Thompson Board report, why did it miss "the point about the danger of an all-oxygen cabin"? Two possibilities occur to me. First, with 3,000-plus pages of detail, the board simply did not understand the problem. This is very difficult to accept, but astronaut Frank Borman, a member of the board, erroneously describes the spacecraft oxygen pressure on page 175 of his book *Countdown*. This leads one to wonder if the board seriously reviewed and debated the oxygen inflation problem. Second, with program dedication at the highest possible level, an institutional defense mechanism was probably involved. Also, the old Washington syndrome, "Don't lie to Congress, but don't be a blabbermouth with the truth," may have been operating. To this day, no NASA publication I have seen or heard of has addressed the fact that the unnecessary superpressure of oxygen on the pad was never mentioned in the spacecraft specifications, or the fact that North American's responsible engineers had no idea of this dangerous procedure before the fire.

J. Leland Atwood
Vista, California

Editors' note: Atwood was president of North American Aviation when the Apollo launch pad fire occurred.

Lindbergh's Crate

Larry Ross, the new owner of Lindbergh's crate (Soundings, June/July 1990), might like to listen to the recording "Lindbergh's Crate" by the Canterbury Country Dance Orchestra. It's in jig time. The flute solo is



played by Deanna Stiles, who, the liner notes say, "lived in the crate for a while." The tune appears on the Canterbury's "Belle of the Contra-Dance" tape, available from F&W Records, Box 12, Plymouth, VT 05056.

David Gartrell
Victoria, British Columbia, Canada

Turn Down the Volume

I served a three-year tour of duty as a jet mechanic at Sembach Air Base, West Germany ("NATO's Noise Problem," August/September 1990). During my first week of work the base was strafed in a mock attack by a fighter flying at rooftop level and near-Mach speed. As a 19-year-old airman, I thought it was the neatest thing I had ever seen. Jets diced through the sky and buildings shook as if rumbled by an earthquake. Ground crews set off smoke bombs, "destroying" our shelters and sending us hustling for gas masks. It was better than a show at Universal Studios.

Today, as a flight instructor and engineering student, I must side with the German civilians on noise abatement. As East-West relations warm up and Soviet missiles get scrapped, the toll is increasingly harder to justify. If the flights can't be conducted over sparsely populated areas, then perhaps the simulator is the best place to stage this imaginary war.

David A. Royce
San Luis Obispo, California

Titan Time Capsule

Bob McCafferty's "Relic From the Cold War" (Collections, August/September 1990) was a very accurate description of what is, in effect, a time capsule that preserves an important part of American military history. I am a former Titan II crew commander and I visited the museum just after helping close down the Titan wings at McConnell and Little Rock Air Force Bases. The tour was wonderful, and the site looks just like it did for the 225 alerts I pulled.

Captain Mark W. Clark
Grand Forks Air Force Base, North Dakota

The Battle of Britain

Your fine tribute "The Last of the Few" (June/July 1990) evoked many memories for me. In the summer of 1940 I was a 16-year-old student at Wimbledon Art School, but after our home suffered bomb damage I moved with my family about 30 miles south


CO

"Grown-ups tell us, 'Just say no.' That's easy for them to say."

"Maybe they forgot what it's like.

"At parties, at school, kids are saying to try this or do that, and they're my friends. I mean how many times can I hear I'm a loser.

"Sure I'm scared of drugs. It's just there's so much pressure. You want to say no. But you can take a lot of heat for it."

Simple yes-no decisions aren't so simple when they involve kids and drugs.

That's why IBM has helped develop a computer-based, interactive video program that's now in schools. It simulates realistic social situations, and allows kids to make choices—about drugs, about alcohol, about themselves—and to experience the consequences, but without getting hurt.

The program is sponsored by the National Federation of State High School Associations, and preliminary results have been extremely encouraging. To learn more about this program, write to us at IBM, P.O. Box 3974, Dept. 973, Peoria, IL 61614.

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to Guileford, Surrey. I became a nurse's aide at the Royal Surrey County Hospital, which was situated right beside a railway junction, making it the target of many air attacks. I celebrated my 17th birthday standing with others in the courtyard of the casualties' entrance, fascinated by a dogfight immediately overhead. Then a hail of machine gun clips forced us back. At night we would watch appalled as the skyline of our beloved London blazed. The knowledge that friends and family were in the midst of the conflagration was agonizing to us. Until my mother stepped off the train the next day, we did not know whether she had survived that night's raid.

Marjorie Terry Doster
St. Simons Island, Georgia

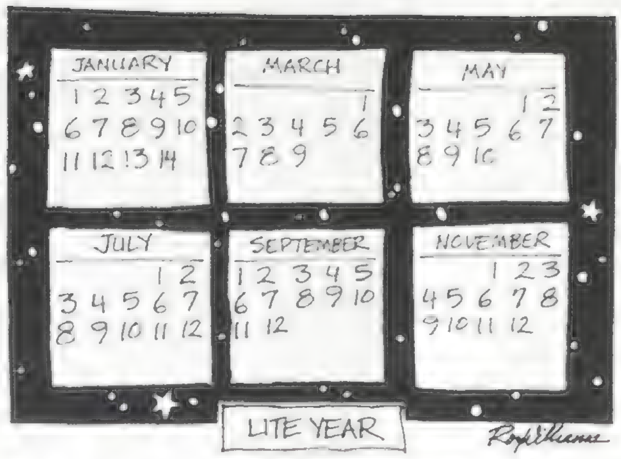
Ron Dick's review of Richard Townshend Bickers' *The Battle of Britain* (Reviews & Previews, August/September 1990) seems a bit harsh. If some of the book's contributors moralized, it's because doing so was the antidote to Axis propaganda and efforts to demoralize Allied forces and their civilian supporters. That these same views survive in the memoirs of the various contributors only adds to the flavor of the thing, in my estimation. But to condemn a whole book on this score is itself an exercise in moralizing.

Daniel F. Burgess
Temple Hills, Maryland

As a recruit in the Army Air Corps in October 1942, I witnessed daily flights by survivors of the Battle of Britain, who explained rather haughtily that they had come over to show the "colonials" how to fly. Never waiting to taxi out to the flight strips, the Brits simply jumped into their "kites," as they called their airplanes, and immediately took off directly in front of the hangars, often missing the control tower by inches. One impatient fellow, whose airplane was on the far side of the hangar, joined the other pilots in his group by flying right through the hangar at a height of ten feet. He made it out safely, but an American mechanic working on an airplane looked up, saw the approaching Brit, whirled around, and smacked his forehead on the pitot tube of the wing's leading edge. He was knocked cold.

Everett M. Brown
Bellevue, Nebraska

Am I one of the few who read your sensitive article on the Battle of Britain in the June/July issue and then went on to read your review section? The review of Richard Hough and Denis Richards' book includes a Women's Auxiliary Air Force sergeant's moving memory of a young



Luftwaffe reconnaissance pilot who was shot down in flames and "screamed and screamed for his mother . . . the whole way down . . . ." Then I was treated to a review of a video game in which the player fired at a Spitfire that "fragmented" and his gunner got another that "hurtled toward the water, trailing bits of flame." The game is called "Their Finest Hour"! I imagine the update will feature someone screaming for his mother. Did those young men die so that middle-aged "avid player[s] of military video games" can revel in counterfeit glory? Like the WAAF sergeant I almost went outside to be sick. I love these fine aircraft and I respect the memory of the young fliers who did what had to be done.

Steve Roberts
Malibu, California

There Has to Be a Catch

Collecting and beaming back to Earth multi-megawatts of electricity sounds like a great idea ("300 Billion Watts, 24 Hours a Day," June/July 1990). No nasty soot, smoke, carbon dioxide, or radiation. No more dependence on finite Earth resources. Pure sunshine—virtually unlimited. But there's a catch. The use of sunsat technology will heat the planet (imagine Earth on a rotisserie in a giant microwave oven). The heating might not be as rapid as we are allegedly experiencing from the greenhouse effect, but vast quantities of solar energy, transmitted via microwave radiation and then electricity, can only raise our planet's "energy quotient." Electricity is eventually dissipated as heat, and unless we find a means to beam that heat back into space, we haven't solved the essential problem.

Newton W. Miller
Redlands, California

Pressure for Profits

In his essay "A Call for Quality" (June/July 1990) Allen R. Stubberud labors under the naive misapprehension that reputation and quality are more important in the U.S. aerospace industry than profitability and predictability. Although quality is desirable, profit has taken the front seat, and Stubberud seems to overlook the fact that the system is set up to encourage such a shift in priorities. The days of the barnstorming, maverick aircraft designer who comes up with a Mustang when he's supposed to build a transport are over. The president of General Dynamics, before answering to aviation historians in the pages of *Air & Space* 20 years hence, must please his stockholders by the end of the fiscal quarter. Some of the changes must come from the *buyer* side. The Pentagon finds it difficult to "just say no" to projects—however poor they may be—that enjoy wide congressional support.

The other source of change must come from manufacturers like Burt Rutan who are willing to assume all risk in development outside the limits imposed by the Pentagon. This would help cure the make-a-buck malaise that infects all who do business with the men in blue.

Russell Burgos
Chicago, Illinois

Shooting Ourselves in the Foot

After reading "Shooting the Stealth" (Groundling's Notebook, August/September 1990) I was very surprised that such an august publication as *Air & Space/Smithsonian* would applaud citizens for literally spying on their own military and selling the results for monetary gain. Publishing such pictures makes them available to the world's photograph enhancement fraternity. The last paragraph of the article saddened me beyond measure. Where else would it be safe to test planes if not in the sanctuary of your own skies?

E.R. Measures
West Vancouver, British Columbia, Canada

Cereal Numbers

Reading about Thunder Jets candies (Reviews & Previews, August/September 1990) reminded me of an experiment conducted in the late 1950s when I was a physicist at the Naval Ordnance Laboratory in White Oak, Maryland. At that time the lab boasted a "hypervelocity flight test facility" that consisted of a large-bore rifle that fired down a long corridor lined with shadowgraph and other instrumentation. A backstop was placed at the end. One evening a fighter flying over Washington broke the sound barrier, and at the lab the

next day there was considerable discussion concerning the actual source of the double sonic booms. The following day someone brought in a small one-piece plastic model of a supersonic fighter—the prize from a box of cereal—and placed it in a lightweight split cylinder that functioned like the wad in a shotgun shell. The assembly was inserted into a cartridge hand-loaded to produce a velocity of about Mach 1.1 and fired. The shadowgraphs showed the model producing three shock waves: one each from the nose, wings, and tail. However, the nose and wing shock waves merged, which is why we heard only two sonic booms.

As far as I know this "landmark" research has never been published, nor has the manufacturer of the test aircraft (which was destroyed in the landing) been informed. I've often wondered what Post or Kellogg would have thought.

David McLanahan
Marlow, New Hampshire

"Maybe it is *a closed universe."*

The First Lady and the Naked Lady

I have a little more information to add to Samuel G. Burtis' letter "The Navy Had Nose Art Too" (June/July 1990). The PB4Y with the naked lady and the caption "Open Bottom Baby" belonged to VB-104. All the aircraft of this squadron bore similar paintings. When "Open Bottom Baby," piloted by Commanding Officer Harry Sears, flew First Lady Eleanor Roosevelt into Guadalcanal from New Hebrides on her tour of the combat zone, the name was temporarily painted out as a concession to the occasion. But the naked lady touching her toes remained.

J.L. Burke
Lexington Park, Maryland

Corrections

In "The Last of the Few" (June/July 1990) Wing Commander Johnnie Johnson is described as the Battle of Britain's top ace. Johnson was the leading Royal Air Force pilot in the war but not the top ace in the battle. That honor belongs to a Czech pilot named Frantisek of 303 Squadron.

Terence T. Finn
Bethesda, Maryland

"Improbable Journey" (June/July 1990) states that *City of the Angels* is being restored at an airport in Fredericksburg, Virginia. The restoration is actually being done at National Airport in Washington, D.C., by Kenneth Garland, who works for the University of the District of Columbia.

Chris Salman
Arlington, Virginia

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National Air and Space Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

Astrophysical Lecture Series "From Sunbeams to Infinity: A Century of Smithsonian Astronomy." Each Wednesday in October. Einstein Planetarium, 8 p.m.

Strategic Bombing Film Series *On the Beach,* October 26; *War Games,* November 16. Langley Theater, 8:30 p.m.

Seminar Sign-up Registration opens in November for "Mutual Concerns of Air and Space Museums," which is scheduled for February 27–March 1 in Washington, D.C. For more information call Patrice Savery at (202) 289-1818.

October 4 "Eisenhower Centennial Space Roundtable." Distinguished participants examine issues related to our future in space. Ripley Center, 9 a.m.–5 p.m. For more information call Linda Hamp at (202) 639-5110.

October 6 Monthly Sky Lecture: "The Vanishing Night." Geoff Chester, NASM. Einstein Planetarium, 9:30 a.m.

October 11 General Electric Aviation Lecture: "Breaking the Bounds." Chuck Yeager, USAF (ret.). Langley Theater, 8 p.m.

October 15 Jazz Performance: "Most Distant Galaxy." Jane Ira Bloom and trio. Einstein Planetarium, 8 p.m.

October 27 One-Man Performance: "Apollo to the Moon." Actor Kevin Reese portrays the history of manned space exploration. Einstein Planetarium, 9:30 a.m.

November 3 Monthly Sky Lecture: "How Big Are Stars?" Ken Johnson, Naval Research Lab. Einstein Planetarium, 9:30 a.m.

November 7 Strategic Bombing Symposium: "The Bomb and the Postwar World." Includes participants from the Kennedy and Johnson administrations. Langley Theater, 8 p.m.

November 8 General Electric Aviation Lecture: "The Battle of Britain." Roland P. Beamont, RAF (ret.). Langley Theater, 8 p.m.

November 17 Children's Program: "They Dwell in the Sky." Ellen V. Sprouls, NASM. Einstein Planetarium, 9:30 a.m.

Planning a Smithsonian Visit? The Associates' Planning Packet is yours for the asking. Send a postcard to Associates' Reception Center, Smithsonian Institution, Washington, DC 20560, or call (202) 357-1729.

Museum Hours Most Smithsonian museums are open 10 a.m. to 5:30 p.m. daily. Please note that the Associates' Lounge will be closed on October 17.

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Drag of the Intruder

Every so often the planets align in such a way that the United States Navy and the National Hot Rod Association feel compelled to meet on a runway and match a drag racer against a Navy airplane hooked up to a catapult. In May 1975 Tom "Mongoose" McEwen and his funny car went up against an F-14 in a showdown at Maryland's Patuxent River Naval Air Station, and in 1986 "Big Daddy" Don Garlits faced an F/A-18 at New Jersey's Lakehurst NAS in a car that was later placed in the Smithsonian's National Museum of American History. On both occasions the jets won handily by about 0.2 second.

Last year, Gary Ormsby, a California car dealer ("The Cars Won't Fly," August/September 1986), won the NHRA's top fuel division, which made him the natural choice to meet an A-6 Intruder last June at Lakehurst for a third jet-vs.-car blowout.

The day started out hot and hazy. Ormsby's crew had rolled in the previous evening with a semi that carried the racer and what appeared to be a complete machine shop. The crew spent most of its time taking the dragster apart and putting it back together. The race team's traveling road show, all bright reds and yellows against the drab grays and browns of the military base, looked like a Hawaiian shirt at a wake.

By mid-morning a crowd had begun to gather and a tow tug rolled the A-6 onto the ramp near Lakehurst's "Fat Cat," a new, more powerful aircraft carrier catapult under development. A public address system began playing the music from *Top Gun* over and over. The Ormsby crew sprayed the runway with a gooey substance that was supposed to help the dragster's tires stick.

The music finally stopped and Rick Lalor, an NHRA spokesman, announced the rules of the race. Each machine would get three timed runs, but for safety reasons they would not race side by side. Then Lalor and a nervous Navy safety officer in a bright yellow jersey turned the media army loose to take pictures and do interviews. One reporter asked the A-6 pilot, Commander Ralph Miko, if he'd ever done anything like this before. He hadn't. Then she asked *why* he was doing it. "Because the people I work for told me to," he said.

Ormsby's crew towed the dragster to an area where a pair of official NHRA timing lights at the start/finish lines and a "Christmas tree"—an array of lights on a short pole used to start drag races—had been set up. Ormsby climbed into a fireproof suit, put on a helmet, then belted himself into the cramped cockpit of his race car. His crew inserted a starter motor into the back of the 496-cubic-inch racing engine and spun it up. The engine started, crackling and spitting angrily. Ormsby smoked the tires once to heat them up, and the crew pushed the idling car into position, all the while trying to wipe sand from the huge slicks on the rear axle. Then the Christmas tree turned green, Ormsby hit the throttle, the rear tires grew about six inches in diameter from centrifugal force, and in a cloud of white smoke the dragster jumped down the track, singing one brief note like a bassoon from hell.

After that split second the car rolled gently to a stop, its engine shut down. Ormsby had clocked 3.056 seconds, and now it was the Intruder's turn.

The A-6 crew scrambled aboard and started the engines. But the crowd wouldn't clear the area, and the safety officer, fearful of a mishap, held up the proceedings. Finally Miko went to what sounded like half thrust, then full throttle. The A-6 howled like an exploding locomotive, a catapult crewman signaled "Launch," and the 13-ton airplane leaped as if it had been stuck by something sharp. A cloud of heat and stinging sand washed over the crowd.

Something went wrong with the clocks

Care to place your bet on which speedster won this drag race?

GEORGE C. LARSON (3)

on the first try, but on the next two runs the Intruder clocked 2.30 and 2.20 seconds. The crowd thinned, but Ormsby's crew tore into the car, adjusted the clutch, and reduced the supercharger boost to try to compensate for poor traction caused by the sand. Ormsby gamely came back for a second try but could do no better than 3.086 and called it a day. As the dwindling crowd headed for home, the safety officer smiled for the first time all day. "It's over," he said. "Now when I retire in two years it won't be to where they make license plates."

—George C. Larson

NASA-LANGLEY

A fleet of what look like little stealth bombers is stirring up the Chesapeake Bay in an attempt to solve a recurring summertime problem—the suffocation of sea life caused by the stratification of cold and highly saline water, which impedes the migration of oxygen. Researchers from the Virginia Institute of Marine Science, aided by a NASA-Langley wake vortex expert, are putting the final touches on Project Water Wings, a series of 20-foot-wide swept wings that will be submerged in the bay and its tributaries. The wings will create vortex turbulence in the tidal current, which will break up the stagnant layer and distribute oxygen to the bottom.

The Red Rocket's Glare?

As sole U.S. agent for the Soviet Glavkosmos space agency, Art Dula, president of the Houston-based Space Commerce Corporation, has been trying for years to marry the Soviet Union's Proton rocket to U.S. payloads. His efforts are now beginning to pay off: Florida Spaceport Authority officials are considering his proposal to launch Protons from Cape Canaveral.

The hard-driving Dula sees the workhorse rocket as the ideal launcher for massive communications satellites built by U.S. aerospace firms. But his entrepreneurial efforts came to a screeching halt in 1987 when the state department ruled that such payloads are considered munitions and thus could not be exported to Eastern Bloc countries.

Today, however, a new commercial space policy awaits presidential approval, one that sanctions the launching of U.S. satellites by Soviet rockets. But there's a catch: the launches will have to occur outside the U.S.S.R.

After considering potential sites in Australia, Hawaii, and Brazil, SCC concluded that Cape Canaveral was the logical choice. Some of the abandoned pads could be converted for the Proton's use, and last year Florida created the Spaceport Authority to encourage just the kind of space business that SCC has been drumming up.

"In many ways it makes a lot of sense," says Edward Ellegood, Spaceport Authority operations manager. The authority had anticipated foreign bids, and Ellegood says he wasn't a bit fazed when SCC announced its intentions last July. Administration officials, however, doubt that the White House will approve the plan.

SCC executive vice president William Wirin shrugs off the doubts, as well as complaints from aspiring U.S. launchers that the Soviets provide unfair competition. He says the Proton offers profitability, availability, and reliability not easily matched. Given the right political tailwinds, he predicts, a gleaming white Proton could be arcing into the Florida sky in as little as three years.

—J. Kelly Beatty

Update

Autogyro: The Sequel

Autogyros may be rolling off a production line in Kentucky this month ("The Autogyro and Its Legacy," December 1989/January 1990). Farrington Aircraft Corporation, which built 68 gyroplanes before declaring bankruptcy in 1966, has formed Air & Space America to build model 18A autogyros priced at $75,000.

Mine Over Matter

"The nation that fails to expand historically collapses."

Thomas Budnick is explaining his rationale for filing over 60 mining claims for

WRIGHT FLYER (1903)

SPITFIRE (1936)

SOPWITH CAMEL (1916)

MESSERSCHMITT Bf. 109E (1939)

DOUGLAS DC-3 (1935)

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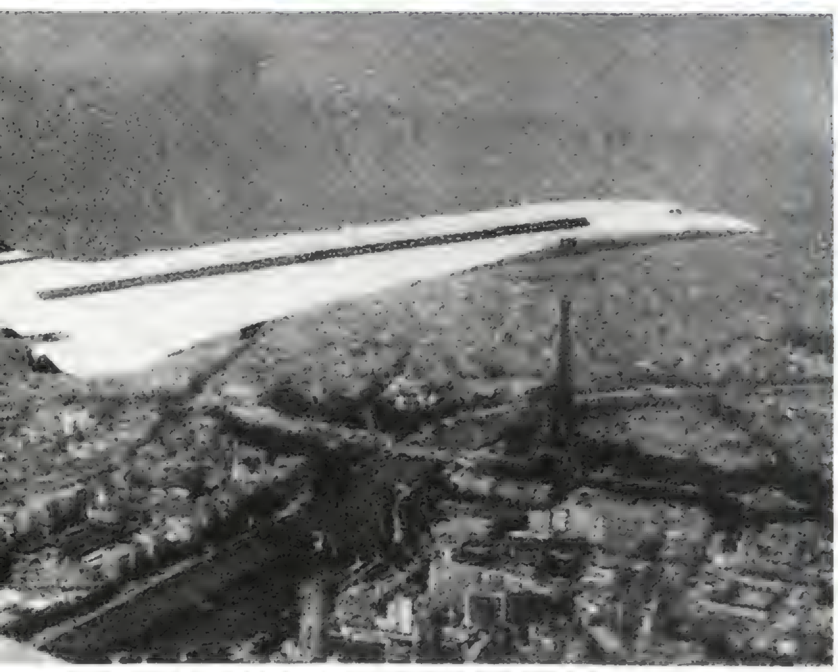
GRUMMAN F-14 TOMCAT (1972)

BOEING B-17 FLYING FORTRESS (1943)



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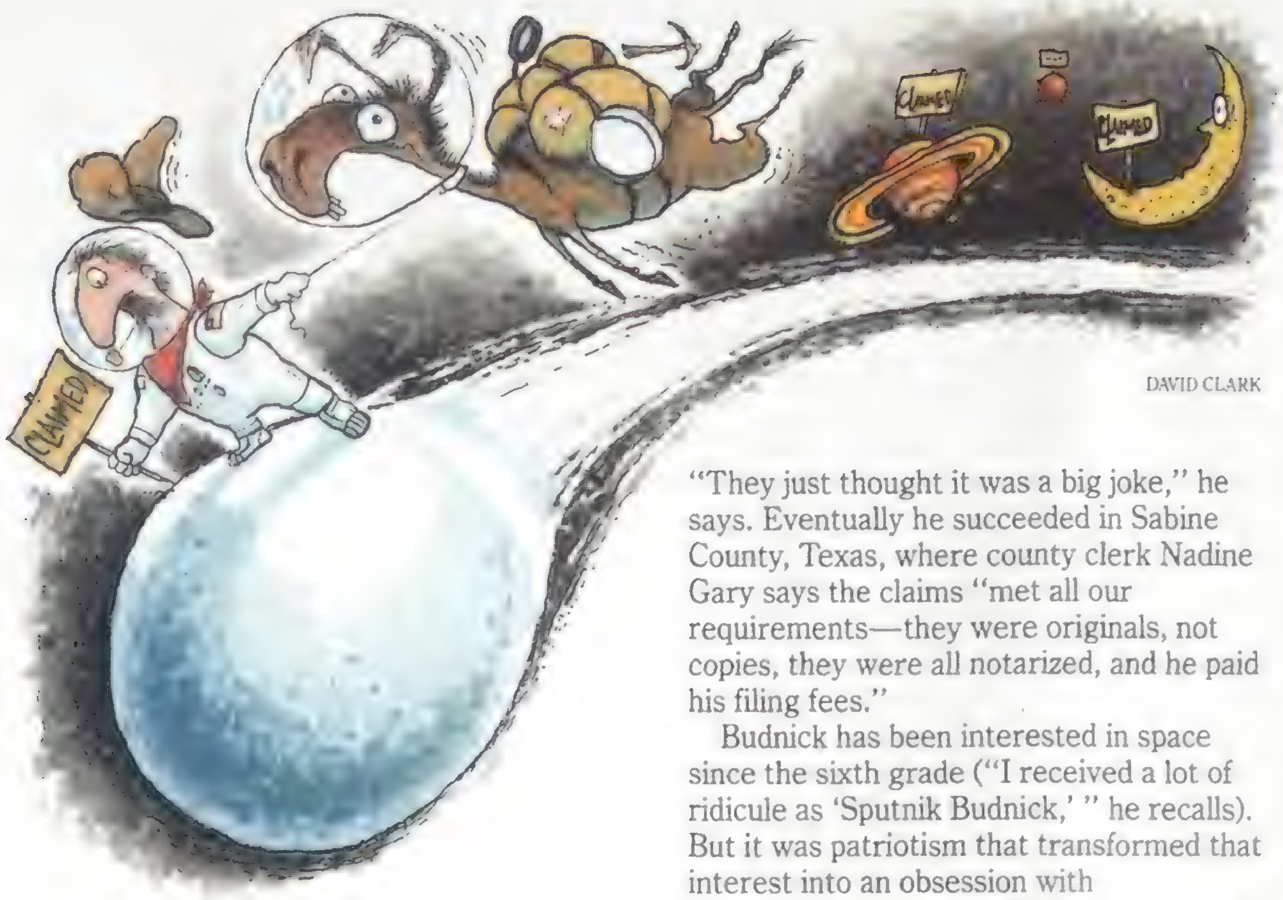
The History of Aviation in Pewter



DAVID CLARK

the moon, Mars, Jupiter, several asteroids and galaxies, and even the sun. The 43-year-old former social worker says he has claimed "quite a bit" of the moon and Mars thus far and has given the plots names like New Dallas, Mayflower Compact 2, Davy Crockett 1, and The Sun Shines on the United States (his solar claim). Though he doesn't expect most of it to be mined in his lifetime, Budnick does believe lunar mining holds promise in the near future. "The secret to exploration is to get rid of heavy Earth gravity," he says. "Get the nuclear fusion reactors up to the moon, mine the moon, and blast out to Mars and the outer planets."

Budnick says all his claims have been filed in accordance with the nation's General Mining Law of 1872, "which provides for the expansion of the United States." Nonetheless, his first attempts to file claims some eight years ago were denied by every county in his home state of Massachusetts, plus many in other states. "They just thought it was a big joke," he says. Eventually he succeeded in Sabine County, Texas, where county clerk Nadine Gary says the claims "met all our requirements—they were originals, not copies, they were all notarized, and he paid his filing fees."

Budnick has been interested in space since the sixth grade ("I received a lot of ridicule as 'Sputnik Budnick,' " he recalls). But it was patriotism that transformed that interest into an obsession with extraterrestrial mining. Budnick filed most of the claims, including acreage on the moon and on the asteroid Vesta, in the name of the United States. "They state the country that mines astrofuel on the moon will be the leading economic, political, and military power of the 21st century," he says, referring to a 1988 University of Wisconsin study on mining lunar helium-3.

Budnick also speaks of continuing America's "manifest destiny." "If you look at American history," he says, "Thomas Jefferson's $15 million purchase of the Louisiana territory, which exceeded his constitutional powers, was dismissed as worthless wilderness, Alaska was known as Seward's Folly, and overthrow of [Hawaiian] Queen Liliuokalani was termed highly imperialistic."

True, but isn't his 20th century gold rush equally imperialistic? Well, he says, he's not really hurting anyone: "Instead of spending my Saturday nights on pizza and beer, I'd rather file a mining claim. It only costs me $7."

He also points out that he hasn't filed a single claim in his own name. But he has claimed some 865,000 square miles of an as-yet-undiscovered 10th planet, which he was hoping the ill-fated Hubble telescope would find, for the heirs of the *Challenger* astronauts, as well as plots for Saint Joseph, the heirs of President Franklin Pierce, and "the good and fair people of Texas," among others.

None of these claims, he believes, violates existing space treaties that prohibit private ownership of extraterrestrial resources. "Experts call those treaties murky and weak," he says, "and the latest United Nations moon treaty has not been ratified by the U.S. Senate." But couldn't a legal brouhaha develop someday between the heirs and an interplanetary mining corporation? "We'll give 'em a good hassle," he says.

—Wes Eichenwald

Update

Space Services Stumbles

Commercial launch company Space Services Inc. suspended operations last July after losing its primary financial backer (Soundings, June/July 1989). "They don't have the intestinal fortitude for the space business," said SSI president Deke Slayton of Development Ventures' announcement that it had "reached the limit of our funding commitment." SSI needs about $3 million to fund operations until November, when the company will learn if it has won a NASA small launch vehicle contract.

Update

Joint Mission

More than two years in the making, "Starway of Humanity" by Robert McCall and Andrei Sokolov is currently on exhibit at the Phoenix Art Museum in Arizona ("The Cosmos According to McCall," December 1989/January 1990). The six- by 11-foot collaborative triptych will be shown at the National Air and Space Museum next spring.

Vulcanized

Picture, if you will, the U.S. Air Force forming a small but elite unit to preserve and fly an aging B-47 Stratojet or a B-70 Valkyrie for airshow crowds. Now imagine that operations of this artifact would be supported by civilians who roam the airshow circuit in a customized coach, selling souvenirs to raise money for flight suits and leather jackets for the aircrew.

And envision these supporters starting an international fundraising campaign to support this noisy, fuel-guzzling anachronism after the military finally orphans it.

Maybe it couldn't happen here. But in Great Britain, the aviation fanatics of the Vulcan Association are on a quixotic quest to keep their icon flying.

The huge delta-wing Avro Vulcan first flew in August 1952. It was the second of the Royal Air Force Strike Command's V-bomber trio of Valiants, Vulcans, and Victors. The great graceful delta is, in the words of one smitten admirer, "a combination of grace, noise, allure, and charisma—and the only one."

The one remaining flying Vulcan, serial number XH558, flew its last combat mission in the 1982 Falkland Islands campaign. For the past four years the aircraft has been primarily a public relations vehicle and the undisputed star of every airshow it attends. But now the 30-year-old bomber is threatened with a belt-tightening measure that will ground the RAF's Vulcan Display Team late this year.

"The good news is that the RAF line is: Now they are actively considering allowing the aircraft to fly on into 1991," says Peter Quirke, a forty-something Welshman living in Birmingham who has spent the last four

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years raising Vulcan money and awareness.

Quirke, a trucking company driving teacher who at age eight fled in terror at his first glimpse of a Vulcan, founded the Vulcan Association in 1987 with some £114 ($200) of his own money. His goal is to raise enough to keep XH558 airborne. "She is, quite simply, too rare, too beautiful to lose," he rhapsodizes, "and as long as there is a breath of life in her she must do what she was born to do—fly."

Quirke has recruited a dedicated group that spends the airshow season living in a converted bus, raising money, and spreading the Vulcan word among the five million people who see the aircraft fly each year. "We know that only the RAF has the necessary skills to keep her aloft," says Quirke, "but we have the chance to preserve something unique. Every line and curve of her speaks of brute force and elegance, and we can keep her airworthy into the next century."

Though the Vulcan Association, with some 6,000 members worldwide, has raised almost $200,000 in less than a year, it costs nearly $1 million a year to fly and maintain XH558 and its crew of five. "We know full well we need Air Force involvement and goodwill," Quirke says, "because the Civil Aviation Authority just wouldn't allow her to buzz over Britain being operated and maintained by a bunch of amateurs."

—*Thomas Wm. McGarry*

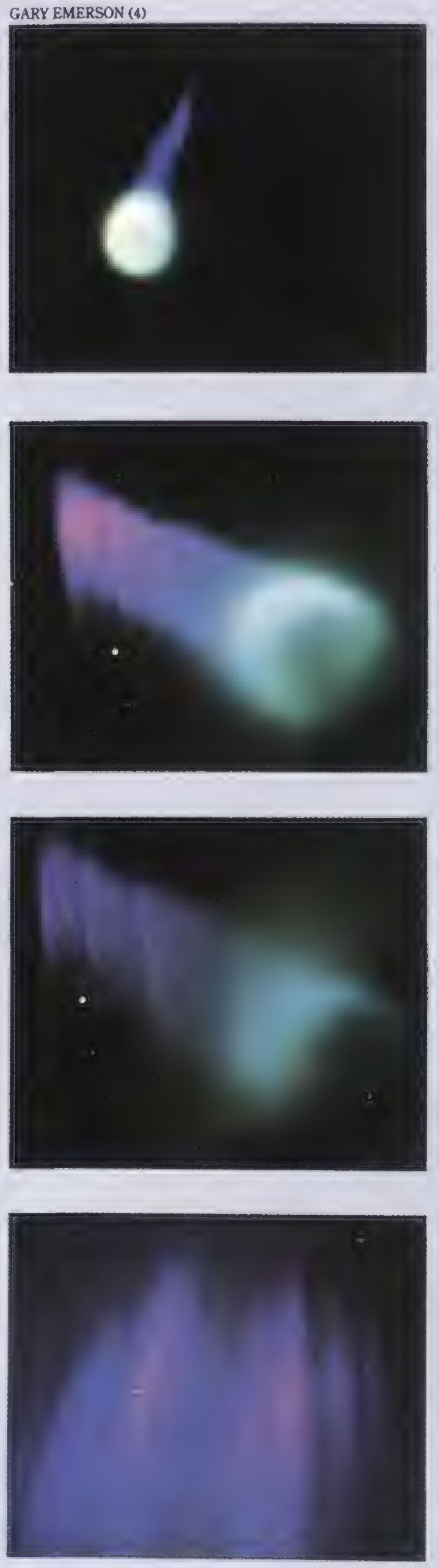
Update

Moving Up, Stepping Down

Edward Stone, a physics professor at the California Institute of Technology and project scientist for the Voyager program ("Goodbye, Voyager," December 1989/January 1990), has been named director of the Jet Propulsion Laboratory in Pasadena. Stone will replace retiring director Lew Allen this December.

Tetsuya Fujita, discoverer of the microburst phenomenon ("The Might of the Microburst," August/September 1986), will retire in December after some 30 years as professor of meteorology at the University of Chicago. "The Tornado Man" will continue his research and work on his memoirs.

GARY EMERSON (4)



The evanescent glow of high-altitude chemical releases will color the night skies in the western hemisphere early next year. The Combined Release and Radiation Effects Satellite tests, designed to study Earth's magnetic field and upper ionosphere, will resemble this April 1990 series of barium releases over central Canada, which prompted numerous UFO reports.

Broken Arrow

On February 16, 1958, the *New York Times* ran a small article in its back pages headlined "Jettisoned Weapon Hunted." The piece reported that the Air Force and Navy were conducting a joint search operation off the coast near Savannah, Georgia. According to the article, the Department of Defense said it was looking for "the component of a nuclear weapon jettisoned by a B-47 bomber." What the Air Force failed to point out was that the missing "component" was actually the entire bomb, minus only its detonating capsule.

The military has code words for mishaps that involve nuclear weapons. The most serious accidents, those in which a weapon is lost or an area contaminated with radioactivity, are called "Broken Arrows." The search off the Georgia coast was the result of a Broken Arrow, one that occurred when a B-47 and an F-86 collided in the early hours of February 5.

It should have been a routine mission. The six-engine B-47, part of the 19th Bomb Wing, had taken off from Homestead Air Force Base in Florida with Air Force major Howard Richardson at the controls. A career military pilot, he had flown B-17s during World War II. Behind him in the cockpit was copilot Robert Lagerstrom, a self-described "short-timer" in the Air Force. In the airplane's nose sat Leland Woolard, who was filling in for the regular radar-observer. Also aboard, in the bomb bay, was a 7,600-pound hydrogen bomb.

In 1958 the public felt very differently about nuclear weapons. Most people believed hydrogen bombs protected the United States by keeping the Soviet Union from launching a nuclear attack. Anti-nuclear activist groups were virtually nonexistent. During training missions, Air Force flight crews routinely practiced loading, carrying, and dropping nuclear weapons. "We carried the weapons on missions just to simulate a 'go to war'-type situation," remembers Lagerstrom. Even if the idea had been to give a crew the capability to suddenly divert to an actual combat mission, these bombs could not have been exploded on short notice anyway, because the flight crews didn't carry the detonators. In a working bomb, a chemical explosion sets off a fission explosion, which in turn creates temperatures high enough to set off the fusion bomb. The fission core—essentially a separate atomic bomb—was not installed in the B-47's Mark 15 thermonuclear bomb on the night of the accident.

For this mission, Richardson and a second B-47 would take off on February 4 and fly a course for simulated bombing runs just outside Radford, Virginia. While they were over another area, the two bombers

DAVID CLARK

would evade mock enemy attacks from fighter jets. What Richardson and his crew didn't know was that F-86 Sabre jets from the 35th Air Division had been ordered to surprise the B-47 crew by intercepting them off the coast of Georgia, outside the mission's simulated enemy territory. It would be a surprise with unforeseen results.

The night was clear and cold with a full moon illuminating the contrails streaming behind the bombers. The flight to Virginia was uneventful, and after finishing their bombing runs the two B-47s turned back for the return trip. Ahead of them, fighters of the 444th Fighter Interceptor Squadron, based in Charleston, South Carolina, were preparing their surprise attack.

Just after midnight Richardson received a message from the other bomber that "he had just been under fighter attack, by a single fighter seen to approach from left to right." The attack was later determined to have come from the three F-86 Sabre jets of Pug Silver Flight.

"We had completed the main part of our mission, and as the saying goes, we were at 35,000 feet sitting fat, dumb, and happy on our way home," says Lagerstrom. "We had also shut down our detection gear, which would give us an indication if someone was running an intercept on us."

Clarence Stewart, flying one of the Sabres, climbed above Richardson's bomber with the idea of diving onto it. As he approached, Stewart concentrated on his radarscope. The instrument was designed to tell him the range to his target, but for some reason it led him dangerously close. "I felt a jolt [from the bomber's jet wash]," Stewart remembers, "and the radar still indicated that what I was locked on to was quite a ways down the road, and I looked up and there was just airplane all over the sky."

In the collision, Stewart's wing was sheared off and the B-47 was seriously damaged. "We felt a damn good jolt, and the aircraft commander and I saw a big ball of fire out by the right wing," remembers Lagerstrom. "We knew immediately that someone had hit us, and [Richardson] alerted us for a possible bailout."

In the meantime, Stewart, 24 years old at the time, ejected from his F-86. He was wearing only a thin flightsuit and suffered frostbite during the 30-minute descent. His fighter smashed into a cornfield about four miles outside of Whitehill, Georgia.

Stewart landed "in a little clearing in the biggest damn swamp in Georgia," he recalls. There he passed a cold, miserable night before being rescued by some locals. They took him to the house of a forester, who "brought out the family whiskey and gave me a shot of that and probably saved my life." He would spend over a month recovering from his wounds and frostbite.

In the B-47, Richardson and Lagerstrom peered into the darkness to see how bad the damage was. "We saw that the number-six engine was hanging down at a 45-degree angle nose up," Lagerstrom says. "We must have looked at that engine six or eight times before we noticed that the right wing tank was missing." Richardson was worried that the damaged engine might fall off the airplane. Both pilots could also see a piece of metal sticking up on the trailing edge of the wing.

Richardson immediately radioed nearby Hunter Air Force Base in Savannah, Georgia, to report the emergency. Next the crew debated whether or not to eject.

Despite the damage, the bomber still seemed to be under control. When he was sure that they were over an unpopulated area, Richardson jettisoned the other wing tank to balance the airplane. After shutting off the fuel to the number-six engine, he felt he could keep the airplane flying, although it handled like a "shot-up B-17" and would have to be flown at a higher speed on final approach and landing. He decided to try to make it to Hunter.

Now the question was what to do with the bomb. Richardson and Lagerstrom decided that if something were to happen on landing they would be much safer without the heavy weapon. "If that thing were to shake loose and come forward, we wouldn't have a chance," Lagerstrom says. Furthermore, the runway at Hunter was being lengthened and the construction had left a one-foot lip at the end of the runway. "If we landed short for any reason, the weapon would have come forward into our cockpit," remembers Lagerstrom.

Richardson's first priority was the safety of the crew, so he decided to jettison the bomb. "When we called [Strategic Air Command] to tell them that we were contemplating jettisoning 'hot cargo,' " he says, "it got real quiet on the radio."

The crew felt a slight jolt as the device fell clear of the bomb bay. It was then that SAC came to a decision. "They told me to go offshore 25 miles or something like that and drop it," recalls Richardson, "but I said, 'I'm sorry but I've already dropped it.' " The bomb hit in water that was less than 30 feet deep, just over a mile from shore in Wassaw Sound. Woolard took radar fixes of the drop point.

With the airplane lightened, Richardson guided the bomber in to Hunter. "It was here that we had the roughest time," he says, "because we were trying to keep the right wing up to keep the engine from dragging, and we damn near went off the left side of the runway." The bomber bounced hard once and Lagerstrom deployed the small braking chute. "We turned off the runway, shut down the engines, and then got the hell out of there," says Lagerstrom. "Of course there were fire trucks all around, and it was after we got out of the aircraft that we started shaking," the copilot recalls. "At least I did."

For two months after the accident the Air Force and Navy combed the marshlands off the coast, working at night near the beach and later extending the investigation into the water. Teams examined a three-square-mile area with divers and underwater demolition technicians using hand-held sonar devices and Galvanic drag, a device used to detect electrical currents. On April 16 the operation was terminated and the weapon was considered "irretrievably lost."

The story was soon buried in the onslaught of publicity concerning another Broken Arrow. On March 11 a B-47 from Hunter accidentally dropped a hydrogen bomb into the backyard of a railway conductor in South Carolina. Again, the fission part of the bomb was not installed but the conventional explosive was. It detonated, destroying the conductor's house and injuring him and five members of his family. The bomb left a crater 75 feet wide and 35 feet deep. An article in the *New York Times* mentioned in passing that the Air Force and Navy's search for the bomb dropped into the waters off Georgia a month earlier had apparently ended in failure.

The Savannah story resurfaced again in June, when *Newsweek* ran a small piece. Shortly thereafter, the story of the Broken Arrow off Georgia disappeared for good, only to be replaced eight years later by an even more spectacular nuclear "incident." A B-52 bomber collided with a KC-135 tanker during an air refueling operation near Palomares, Spain. Four thermonuclear weapons—complete with detonators—fell from the airplane, three tumbling onto land while the other settled into deep water off the coast. Unlike the Savannah bomb, the device lost in Spanish waters was recovered, although at considerable expense.

As for the major players in the 1958 accident, all have long since retired from the military. Leland Woolard, the navigator of the B-47, died in 1986. Richardson, the bomber's pilot, seems to regret jettisoning the bomb, even though he had done it to save his aircraft and crew. After receiving the Distinguished Flying Cross for his actions during the accident, he became a B-47 squadron commander, went on to fly B-52s, and now dabbles in real estate. Lagerstrom is today a flight captain for a major U.S. airline. He and Richardson never flew together again. Clarence Stewart was able to prove that his radarscope was defective. He later spent several years flying jets in Southeast Asia, where he was forced to eject from an F-105 fighter after being hit by small-arms fire. He retired from the Air Force in 1977 and spends his time flying his two light aircraft.

It's been more than 30 years since the incidents of that dark night in February, but for Clarence Stewart, Howard Richardson, and Robert Lagerstrom, the memory of what happened is still embedded as deeply in their memories as the hydrogen bomb is in the sea floor.

—*Curt Newport*

The Postmodern Bomber

Low Observable technology, which first surfaced on the Lockheed SR-71, reduces an aircraft's radar and infrared signatures. It also produces exceedingly weird aircraft. The latest manifestations are the B-2 bomber and F-117A stealth fighter. However, recent revelations have made it clear that the carbon-fiber security blanket wrapped around the development of these aircraft was part of an elaborate scheme to trick Eastern bloc nations into directing their research-and-development programs up a blind alley. The stealth programs were merely window dressing that masked development of High Observable technology.

With the end of the Cold War, the slashing of military budgets, and the destruction of part of the nuclear armament, Pentagon heads recognized the need for a completely new type of strategic bomber. So they turned to High Observables, or HOs, the latest acronym in the military litany. The resulting Boeing B-3, which at first glance appears to be a low-technology solution, actually represents the state of the art in HO development.

The B-3 was designed to exploit the situation created by the success of stealth programs. News of the Low Observables had caused potential enemy nations to pour enormous resources into the development and production of counter-stealth radar and anti-aircraft missiles fitted with ultra-sensitive infrared homing heads. The B-2 and F-117 scams achieved their aim long before the latter made its combat debut over Panama. One highly placed source says that during last June's summit meetings, Gorbachev confessed to Bush that the Soviet defense budget was so perilously overburdened by anti-stealth radar and missile development that the entire Soviet economy was in grave danger. Reportedly, Bush felt obliged, in the spirit of *glasnost,* to reveal to the Soviet leader the existence of the B-3 and its new tactical concept. Within a few days, a grateful Gorbachev revealed to Bush his nation's plan to develop an equally novel weapons system.

Details on the new bomber are now being leaked to alert the world that the United States is shifting its deterrent posture as world politics undergo radical change. HO, which represents a mind-boggling shift in military aircraft design philosophy, was conceived by Colonel "Mad Gus" Lowenbrau of Air Force Systems Command. The B-3 airframe, which resembles a "stretch" B-52, is tailored to provide the largest possible radar returns. And its 20 or so (the exact number is classified) refurbished TF-33 turbofan engines from retired B-52s ensure that the aircraft has an enormous infrared signature. Apparently the echo from a formation of B-3s is so large that the mere sight of an incoming bomber wing on a radar screen could be sufficient to terrify an enemy state into complete submission.

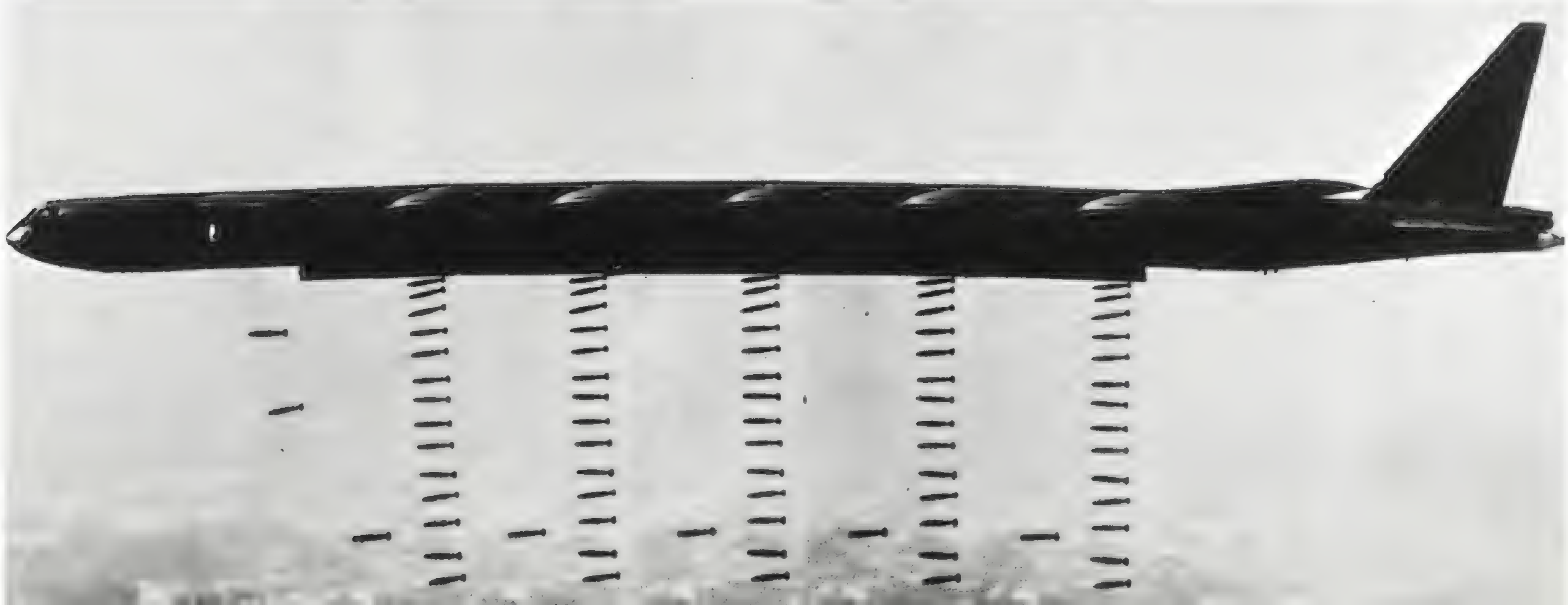
In the near future the Air Force will have considerably fewer overseas bases. Hence, the B-3 specifications called for unprecedented long-range performance. The bomber can reportedly remain airborne for up to 24 hours without refueling. It carries two four-man crews and has a spacious galley, restrooms, sleeping suites, and a pool table. Later versions may incorporate a hot tub.

The B-3 also carries a sophisticated electronic countermeasures suite. In one scenario the B-3's equipment would operate in the enhancement mode, with the aircraft on opposite sides of a five-plane formation transmitting alternately at pre-determined blink rates. Thus a missile heading for the formation would be drawn alternately from one side of the formation to the other. As the missile drew closer its maneuverings would become more and more violent until it passed harmlessly through the middle of the formation.

And the B-3 is cheap. Wherever possible, parts were reclaimed from scrapped B-52s. The B-3 costs roughly $18 million per copy, an extremely low figure for a bomber in this class. According to one source, the low price tag makes the B-3 a likely candidate for endorsement by the Union of Concerned Scientists. Air Force officials are reportedly pleased with the aircraft nonetheless.

—*Alfred Price*

NASM



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THE BLACKBIRD'S WAKE

by Eliot Marshall

At 4:30 a.m. on March 6, 1990, an Air Force SR-71, number 972, took off from its base in Palmdale, California. For the Blackbird, this would be an unusual flight. Its routine missions took it halfway around the planet to photograph military installations in trouble spots like North Korea, the Persian Gulf, and Libya. It skirted the Soviet coast to spy on submarine pens and ferret out radar. The Air Force still won't say how fast the airplane *can* fly, preferring to say that on that March flight it *did* fly 2,242.48 mph, an absolute world record, and that its cruise speed is above Mach 3. It also holds the world record for altitude in horizontal flight: 85,068 feet. Well-informed sources say it will do just fine at 100,000 feet.

Blackbird is the nickname that stuck, but the SR-71 has also been called a dagger, a bat, a manta ray, and habu, *a venomous snake. Its distinctive deadly look came from tapering chines around the fuselage, but they were packed with sensors, not weapons.*

GREG E. MATHIESON/MAI

The Blackbird carries no weapons. Instead it is packed to the gills with optical and infrared imaging systems and electronic surveillance gear. It is also equipped with electronic countermeasures to deflect surface-to-air missiles, but one Blackbird pilot says, "Speed was our primary defense." An SR-71 was never shot down by enemy fire. It took friendly fire to kill the Blackbird.

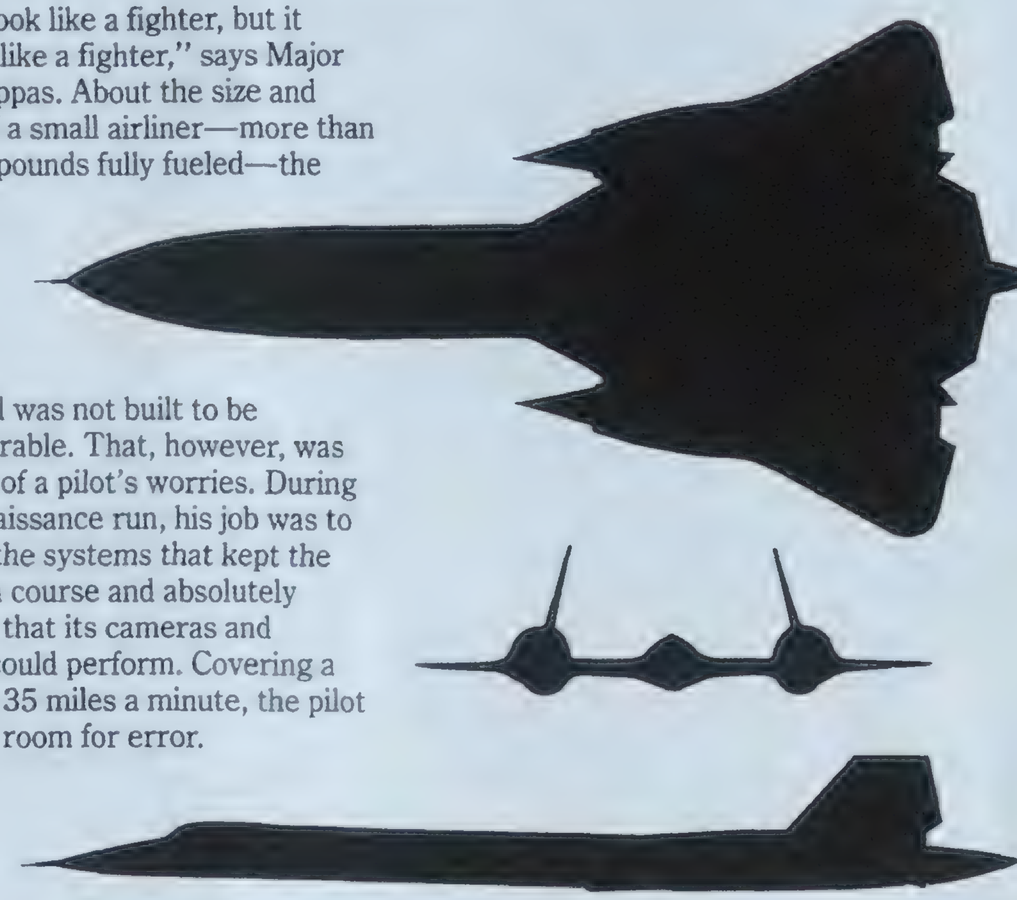
The March 6 flight was the last ride for number 972, and one of the few in the Blackbird's 24-year history of secret operations that had an announced destination and a welcoming party. The party atmosphere was a little thin, however, amid the group waiting at Dulles Airport near Washington, D.C., to welcome number 972 to its retirement home, the National Air and Space Museum. On hand were Lockheed Corporation employees who had built the Blackbird, some ex-pilots, a few retired intelligence officials, congressmen, the director of the museum, and one lone Air Force senior officer—Brigadier General Harold B. "Buck" Adams, pilot of 972 when it set the London-to-Los

Angeles speed record in 1974. The *Washington Post* later noted the absence of Air Force brass. Of the people who were present, many were still bitter over the Air Force decision to retire the Blackbird. The following day Senator John Glenn made the bitterness a matter of congressional record. "The termination of the SR-71 was a grave mistake and could place our nation at a serious disadvantage in the event of a future crisis," he said. "Yesterday's historic transcontinental flight was a sad memorial to our shortsighted policy in strategic aerial reconnaissance."

Strategic aerial reconnaissance—espionage with an airplane—is of course only one of the complex strategies the United States uses to gather information about the rest of the world. Like the pictures it produces, it is seen in different ways by different people. The Cen-

On the Straight and Narrow

"It may look like a fighter, but it didn't fly like a fighter," says Major Terry Pappas. About the size and weight of a small airliner—more than 150,000 pounds fully fueled—the Blackbird was not built to be maneuverable. That, however, was the least of a pilot's worries. During a reconnaissance run, his job was to monitor the systems that kept the SR-71 on course and absolutely stable so that its cameras and sensors could perform. Covering a target at 35 miles a minute, the pilot had little room for error.



Maintenance crews pampered the Blackbird. "It takes eight hours to put it to bed," one crew chief said.

GREG E. MATHIESON/MAI

tral Intelligence Agency, the Defense Intelligence Agency, the National Security Council, the Department of State, and the intelligence arms of the services all have different, frequently competing requirements for information, and the intelligence committees in Congress add their own ideas to the mix. Fights are common, not only about how to collect information but about what information to collect and what it means once it's collected.

One of those fights was waged over the value of the Blackbird. It culminated last fall in a muffled but intense struggle in Congress to prevent the Air Force from killing the SR-71. The Air Force, then led by Chief of Staff Larry Welch, took the position that while the SR-71 was a valuable asset, sophisticated spy satellites had made it a luxury item. Welch, who ascended to chief of staff after heading the Strategic Air Command, was especially sympathetic to SAC priorities and may have been hoping that sacrificing the SR-71 would protect the beloved B-2. Throughout the fight, the general stuck to his guns, so to speak. The SR-71 "can't fire a gun, it can't carry a bomb, and I don't want it," Welch was quoted as saying in 1988 in Rowland Evans and Robert Novak's syndicated newspaper column.

When the Blackbird entered operation in 1966, the Air Force was eager to pay the bills. President Dwight D. Eisenhower had kept the Air Force out of operations by the SR-71's predecessor, the U-2, and now the service wanted in. Journalist William Burrows discussed Eisenhower's misgivings in his book *Deep Black,* a respected analysis of the U.S. technical intelligence system. "Allowing any military service, but particularly the Air Force, to compose its shopping list for weapons based on a threat assessment that came from intelligence it alone collected, processed, and interpreted was absolutely untenable where Eisenhower was concerned," Burrows wrote.

The president also believed that a civilian pilot in an unarmed aircraft would present less of a provocation in the event he was caught. That is why the U-2 shot down in May 1960 over Sverdlovsk in the Soviet Union was flown by

LOCKHEED

Lockheed legend Kelly Johnson designed 40 aircraft but singled out the SR-71 as "the most difficult."

Cold Storage

"There it is," someone said, and everyone in the crowd looked west. For many of the people straining to see the dot in the clear Nebraska sky, it would be their first look at the legend. For all, it would be their last. SR-71 number 964 was making its final flight, from its home at Beale Air Force Base in northern California to Offutt Air Force Base near Omaha. Of the 20 Blackbirds left from the original 32, nine were sent this spring to museums around the country, like the Strategic Air Command Museum at Offutt.

As Major Terry Pappas flew the SR-71 over the base for the first of several passes, a colonel excused himself from the group of spectators below. A former reconnaissance systems officer, he could not bear to watch anymore. Lieutenant Colonel Gil Luloff kept watching, though. "It just doesn't seem like a museum piece," said Luloff, a former SR-71 pilot who was assigned to dismantle the program. "You take something that's that cosmic, that capable and still on top of the list record-wise, and put it in a museum . . . it's kind of a dichotomy."

At least three of the aircraft will continue to fly; they were delivered to NASA for use as supersonic testbeds at Dryden Flight Center in California. The remaining eight are in Air Force warehouses.

After a few touch-and-gos, Pappas landed and taxied over to where members of the media waited. Although it wasn't obvious to onlookers at a distance, fuel was probably already dripping from the Blackbird. Since the surface of the aircraft on high-speed runs averaged 550 degrees, conventional tank sealants like O-rings or rubber bladders were out of the question. In flight the aircraft skin expanded and formed a tight seal—an SR-71 could grow as much as six inches—but on the ground when the skin cooled, the fuel tanks would weep.

As soon as the crowd left, 16 maintenance technicians swarmed over 964 to decommission it. The crew ran the engines for 90 minutes to use up most of the remaining JP-7 fuel, which has a higher flash point than conventional jet fuel, and to burn off the hypergolic fuel ignitor, triethylborane. This also heated the engine oil, causing it to thin and making it possible to drain. Afterward, Technical Sergeant Gary Sellers hooked up a hose to pump pressurized nitrogen and JP-7 through the fuel lines to remove any trace of the ignitor. There had been some chatter, Sellers noticed, while the engines were running. When they shut down, everyone fell silent.

"We knew we were at the end then, that that was the last time we'd hear those engines," he said. Sellers' eyes fixed on a remote point. "I've been with the planes for 11 years and it hurts to lose them."

The next day, after the classified gear and ejection seats had been removed, an MB-4 tow vehicle, led by a van, pulled the aircraft, with its canopies hooded, toward the museum gate. The vehicles were followed by another van carrying a solemn group of technicians. At the flightline speed limit of 5 mph, the small entourage resembled a funeral procession. The aircraft was parked just beyond arm's reach of the museum fence, a final protective gesture before curators would begin preparing it for display.

The technicians milled around the airplane, reluctant to leave. One man stretched up and kissed a nacelle. Then everyone gathered for photographs near the fuselage before climbing back into the van.

—*Mike Whye*

After flying at 350 mph to get fuel from a KC-135, the SR-71 took 30 minutes to reach Mach 3.

Francis Gary Powers, a former Air Force pilot who had gone to work for the CIA as a civilian. But two years later, during the Cuban missile crisis, SAC wrested control of strategic aerial reconnaissance from the CIA. According to Burrows, "As the White House saw the Cuban confrontation developing early in October 1962, some kind of military conflict seemed likely. Were that to happen, an Air Force pilot who was shot down would merely be a military officer doing his job; a civilian U-2 pilot in the employ of the CIA, on the other hand, would be shown to the world as a spy and possibly would even be executed as such." Though developed by the CIA, the SR-71 was delivered to the Air Force. SAC operated it from Beale Air Force Base in California.

In the early 1980s Secretary of the Air Force Edward C. Aldridge Jr. ordered a series of studies on the expensive spy, capped by a Defense Science Board review in 1984. The board concluded, according to insiders, that the Blackbird's outer structure, annealed by heat on every flight, was actually stronger than when first delivered. The airframes would last another 30 years. With new innards—digital flight controls and electronic defense gear—and extensive engine work, the aircraft would be good until the 21st century. Accordingly, the Air Force invested in better electronics, new weather-penetrating synthetic-aperture radar, and 60 refurbished engines. After the upgrade, it appeared that the Blackbird had a long service life ahead of it—until the Air Force deliberately drove it into the high-threat area of Capitol Hill.

General Welch made no secret of his dislike for the program. As soon as he took command of SAC in 1985, a year after the Air Force decided to spend $300 million refurbishing the SR-71, he revealed the previously secret program budget to all top officials in the Air Force. For the first time, the SR-71 was made to compete openly for funding like any other military program. A former

GREG E. MATHIESON/MAI

DENNY LOMBARD, LOCKHEED

Skunkworks head Ben Rich says the SR-71 was the only airplane with oil that cost more than scotch whiskey.

defense department staff member, who asked that his name be withheld, says that the reconnaissance community within the Air Force is so small that once the SR-71 was in an open forum, it didn't stand a chance against fighters and bombers.

In 1989 Welch's successor at SAC, General John Chain, told Congress that the SR-71 cost $400 million a year to run, but his figure turned out to be much too high. According to the Pentagon program office, the total cost of running the SR-71 in 1989 was $260 million, including overseas bases.

John Pike, an aerospace expert at the independent Federation of American Scientists in Washington, D.C., believes the Air Force has a legitimate gripe. Their own top-priority programs, he says, the stealth fighters and bombers, are being cut back. At the same time they are stuck with the bill for an aircraft that no longer serves them. The Blackbird's outfit, the Strategic Air Command, has a need for information—likely targets in a large-scale nuclear conflict—that the Blackbird couldn't provide. Because of the effectiveness of Soviet air defenses, no SR-71 has ever overflown the Soviet Union. Ex-pilots insist that the Blackbird is able to electronically outsmart or simply outrun Soviet missiles, but six presidents have elected not to test this conviction.

The Blackbird was very useful, however, to the CIA, the state department, and most frequently, the Navy. But none of these users paid the freight. And the Blackbird cost an outrageous amount of money to operate.

The aircraft required 40 hours of maintenance on the ground for every one hour in the air, according to one pilot. Its two Pratt & Whitney J-58 turbo-ramjet engines gulped its unique fuel in such quantity that the SR-71 could not fly at cruise speed for more than about an hour and a half without refueling. This was not only an expensive operation, it was a logistical nightmare. Tankers had to be loaded and kept on standby in safe airspace whenever an SR-71 ventured out.

Summarizing these costs during a hearing this June on the 1991 budget, and still defensive about the decision to retire the aircraft, Secretary of Defense Dick Cheney told the Senate appropriations committee that the cost of an SR-71 mission was $85,000 an hour.

To the Blackbird's supporters, that cost compares favorably with the costs of other technologies. "The problem with losing the SR-71 is the cost to replace the system," says Bobby Inman, former director of the National Security Agency and once deputy chief of the CIA. "In a perfect world we would have a new platform that could replace it quickly and perform just as well. But the possibility of developing a new platform is not bright." Despite rumors that Lockheed is testing an unmanned Mach 6 replacement code-named Aurora, intelligence experts say that a better Blackbird won't fly in this century.

The existing platforms, the last of the Keyhole, or KH, spy satellites and their successors, are also expensive. Although the cost of the ones that are slowly replacing the KH-11s is still classified (as is everything else about them), the most frequent estimate is $1 billion, and some guesses reach as high as $2 billion when launch costs are included.

These platforms are also startlingly capable, but John Glenn and the Black-

GREG E. MATHIESON/MAI (2)

When a Blackbird was cleared for takeoff, its systems had been at work—and worked on—for 12 hours.

bird's other allies believe that satellites can't do it all. Satellites have the potential to produce more data, but they also run on a predictable orbital track. The latest models can maneuver for special coverage, but that takes fuel, which must also be used to keep them in orbit. Satellites rarely catch a sophisticated nation by surprise.

When the Air Force first tried to zero the Blackbird budget in 1988, Congress restored the program. The Air Force repeated the attempt in the spring of 1989, but Glenn and California representative Wally Herger again challenged the retirement plan.

John Chain responded to Glenn's challenge by pointing out that the Blackbird, unlike satellites, is vulnerable to accidents involving crew (an SR-71 had recently been lost in the South China Sea but both crew members survived). He also noted that the slower, cheaper TR-1, an advanced version of the U-2, could do many tasks as well, especially since it was being fitted with new sensors. Since the maximum cruise speed of the TR-1 is 430 mph, however, one of the tasks it cannot do as well as the SR-71 is survive. The Air Force rejected proposals to outfit the Blackbird with the same advanced gear.

On June 12 Glenn made another impassioned plea for the Blackbird, pointing out that the SR-71 could be used for strategic surveillance if spy satellites were suddenly crippled. A former astronaut, he may have been remembering the aftermath of the 1986 *Challenger* explosion, when the SR-71 again proved its value. As the number of operational imaging spy satellites dwindled and America's launch capability stood frozen in safety reviews, the Blackbird filled the gap. According to Jeffrey T. Richelson, author of *America's Secret Eyes in Space,* for 18 months the overhead surveillance network was down to only one good KH-11 satellite. A second KH-11 finally went up in October 1987. Until then, the fuel and mobility of the lone satellite was prolonged by substituting SR-71s as much as possible.

Representative Wally Herger, whose district includes Beale Air Force Base, took up the SR-71's cause in the House. By the end of the summer, House and

The SR-71 had no flaps or spoilers and, with tires already hot, relied on a drag chute instead of strong brakes.

ERIC SHULZINGER, LOCKHEED

Wearing the 50-pound pressure suit in an SR-71 was "like driving an MG in a football uniform," a pilot says.

Senate conferees for the defense appropriations bill took off the gloves. Accusing the Air Force of "lackluster and unenthusiastic" handling of a national resource, the conference committee restored $210 million for SR-71 operations and at the same time rescued the program from alleged Air Force mismanagement. According to the conferees' report, the system would be placed "in the hands of managers who will more aggressively realize its capabilities"—the Air National Guard.

In the two-year tug of war over the Blackbird's fate, endorsements for the aircraft came in from 40 members of Congress—including Sam Nunn, chairman of the Senate Committee on Armed Services; CIA director William Webster; intelligence officials at the state department; and former Secretary of State George Shultz. Bobby Inman testified on the SR-71's behalf in closed hearings. He expressed the concern that the United States would lose a valuable system at precisely the wrong time. "We may be in for some surprises," he says today, "a whole new set of problems." He is referring to the deployment of weapons of mass destruction, such as poison gas or nuclear arms, by Third World nations. "We need to totally rethink our need for airborne reconnaissance" in light of the changing balance of power in the world, says Inman.

The SR-71 got an opportunity to demonstrate its handiness in assessing Third World trouble in the spring of 1988, when it was assigned to a crucial mission in the Persian Gulf. It scanned thousands of square miles of Iranian coastline for Silkworm missile launchers that hadn't been spotted by satellites. The aircraft uncovered the missiles in several flights, each taking less than an hour. To make a big survey like this, the KH-11 satellite would have taken much longer, and at the time it was being used to take close, high-resolution shots of the same territory.

"What I get from the inside is that General Welch thinks you can strap a camera onto an F-15 and get the same thing you got with an SR-71," said William Burrows. "That might work once in Libya. But what do you do when you have 10 or 15 Libyas?"

In the end, the $210 million allocation provided by the appropriations conference proved too big a target for legislators scrambling to reduce the deficit. To forestall a last-minute rescue, defense

GLEN SUNDERLAND, LOCKHEED

Although tankers stood by, the SR-71 always flew its spy missions solo and at random times to preserve surprise.

secretary Cheney sent a letter to the Senate last November 17 stating that "the SR-71 is simply not a cost-effective solution to our needs at this time." The Senate still came back with money for a standby operation. The protracted, emotional nature of the battle suggests that this time other factors were at work besides cold, hard cash and cold, hard reason. The Blackbird has an unusual effect on people.

For a spy, the SR-71 has always had a high profile. Its existence was first revealed by President Lyndon B. Johnson at a press conference in 1964. LBJ got the name scrambled, though, and switched the letters from RS-71 to SR-71. The misnomer stuck; instead of reconnaissance/strike, the designation became strategic reconnaissance.

In the years since, the Blackbird has acquired a flashy notoriety. Frank Crosby, a spokesman for the Imperial War Museum in London, told the *Air Force Times* that "people from all over the country—indeed, from all over Europe" came to see the airplane at Mildenhall air base in England, one of the Blackbird's homes away from Beale (the other was Kadena air base in Okinawa). The SR-71's appeal is its glamour as well as its power. Sleek, dark, exotic, and arrogant—the Blackbird looks every bit the superplane it was designed to be.

Richard M. Bissell Jr., a former Yale economist, joined the CIA to shepherd both the SR-71 and the U-2 through production. (Bissell was later chief of covert operations, directing the Bay of Pigs invasion and other anti-Castro plots.) "After the first overflight of the U-2, I took the initiative in thinking about a successor," says Bissell, now retired and living in Connecticut. "We knew it would have to be a lot faster, fly higher, and have a smaller radar cross-section." The job fell to the U-2 builders, the Lockheed Advanced Development Projects Office, known as the Skunkworks.

The aircraft Kelly Johnson and his crew first developed was called the A-12. It was to be made of titanium—light, but with a higher melting point than aluminum and thus able to withstand the 550-degree Fahrenheit average surface temperature created by supersonic air. Just about everything in the airplane had to be invented. "Kelly Johnson always maintained—and I believe him—that nobody knew how to make highly stressed structures of titanium of this size," Bissell says. He remembers Johnson coming in one day and dropping a piece of imperfectly

treated titanium on the floor. It shattered like glass. A heat treatment method had to be developed. The engines were experimental. The fuel and lubricants had to be invented. Even the wrenches were different: free of cadmium, which would have left corrosive deposits.

"The greatest technical problem we had in the later stages of development was the leakage of ram air out of the inlet ducts," recalls Bissell. At top speeds of Mach 2, 3, and above, the engines use a "bleed bypass cycle" that directs supersonic air around the turbines and delivers most of the power through an extremely high-pressure ramjet effect. The inlet caused trouble for years.

Hydraulic controls moved the engine's cone or spike in and out, compensating for changes in flight speed by controlling the position of the shock wave in the airflow. Before the system was fully automated in the 1970s, the airplane was prone to what Johnson has called its "most sensational and most confusing problem"—the "unstart." Instead of flowing smoothly through the turbine, air would pile up, says one ex-pilot, "like a barn door" at the inlet, causing the plane to pitch and yaw. "It was like having two big guys grab you and shake the shit out of you," the pilot says. "You could never predict when it would happen, and it was so violent you couldn't tell which engine was unstarted."

When the Air Force decided to buy the A-12 fleet, it installed a second seat for a reconnaissance officer and renamed the airplane—with LBJ's help—the SR-71. Thirty-two SR-71s were built and delivered to the military starting in 1966. Twelve have crashed in tests or accidents, but a crewman has never been lost.

Nobody loves the airplane like the men who flew it. "It's definitely the highlight of our lives," says Major Terry Pappas, who flew Blackbirds for the last five years they were in service. "They become very attached to it—everybody that works with this airplane," despite some unpleasant handling characteristics, like the unstart, extremely limited visibility, and the discomfort of wearing a 50-pound pressure suit in a very tight cockpit. "You know, you can do anything you want to if you want it bad enough," Pappas says. "This airplane makes you want to."

SR-71 pilots consider themselves members of an elite club. Thousands of pilots have flown the F-15, but only 120 have flown the Blackbird. That's only two percent of the pilots who applied for the program. Many SR-71 pilots have wished publicly that the program would be restored. After Welch retired this July, a few said privately that now it has a chance. Major Randy Shelhorse, a particularly outspoken reconnaissance systems officer, told an *Air Force Times* reporter that "reconnaissance has been overlooked. If it doesn't drop bombs or shoot bullets or missiles, the Air Force doesn't want it. They say it's a fiscal decision, but I think it's a political one."

Even after the SR-71 was retired, Welch seemed to resent it. Lockheed and the National Air and Space Museum petitioned the Air Force for a last celebratory flight across the United States, including the chance to set a new record. The request sat on Welch's desk for weeks, says one defense department staffer, and it was only through the intervention of higher-ups that at the very last moment permission came through.

Any decision on reinstating the Blackbird will fall to General Michael Dugan, Welch's successor. The Blackbird's friends in Congress have given him that option by allocating $10.3 million to keep six of the aircraft ready to return to operation. If Dugan believes in the program himself, he will have to convince Secretary Cheney.

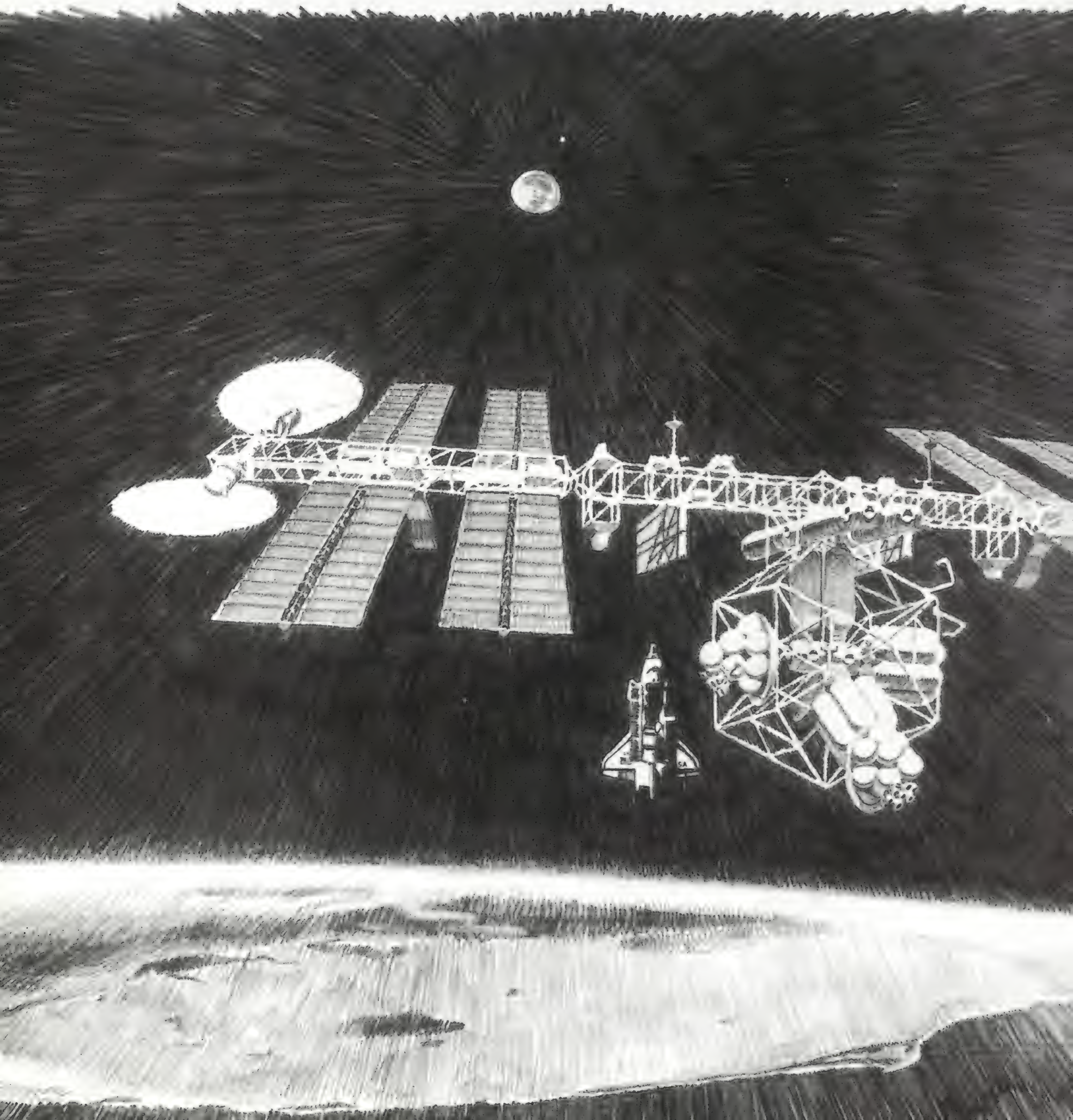
At this time, it is difficult to judge whether the SR-71 is badly missed. The events in the weeks following the record-breaking flight of 972 suggest that it is. In mid-March the White House, relying on inadequate photos, announced that an alleged chemical weapons factory built in the Libyan desert by Moammar Qadaffi had been "massively" damaged by fire. The fire, it turned out, may have been a hoax. In the meantime, the latest spy satellite launched by the shuttle on February 28 failed. By late summer, however, when the confrontation with Iraq imposed a sudden requirement for timely intelligence, the remaining satellites appeared to be delivering the goods.

A Pentagon official recalls the clear and cold dawn at Palmdale when he watched number 972 on its final takeoff. "The exhaust was blindingly white; as the aircraft climbed away, you could see the yellow shock diamonds in it. There were three streams, one from each engine and a small thin line from the fuel vent." The plane flew over the Pacific and seemed to take forever refueling. Suddenly, just after 6 a.m., it reappeared and shot back through the radar speed gates overhead at faster than Mach 3. "Then we heard the bang; it made one hell of a bang."

Now a caged Blackbird, number 972 retired with the title of fastest airplane ever flown from a runway.

MARK AVINO, NASM

The Mars Transit System



A former astronaut presents his plan to make Mars a destination, not just a goal.

by Buzz Aldrin

Illustrations by Carter Emmart

In the late 15th century, European mariners learned to take advantage of the tropic winds that blow steadily westward toward the equator to move their caravels across the vast, trackless ocean. They relied on another system of easterly winds to return them to their home ports. The new routes did not follow direct courses but instead looped along curving paths that sometimes appeared to carry the mariners away from their objective. These trade winds, however, soon became bridges between continents, making possible the great age of discovery.

On July 20, 1989, the 20th anniversary of the first moon landing, I stood on the steps of the National Air and Space Museum with my Apollo 11 crewmates, Mike Collins and Neil Armstrong, listening to President George Bush announce that mankind was about to embark on another great age of discovery. The president proclaimed that the United States would return to the moon and venture on to Mars in the next century.

To undertake a Mars mission in the next 30 years, we have to begin comprehensive planning now. So it's fair to ask what types of spacecraft and flight plans offer the most promise for success on mankind's most ambitious exploration.

Some planners favor a much more massive version of the spacecraft we used in the Apollo mission, which would be assembled at a spaceport in low Earth orbit (LEO) and then propelled beyond Earth's gravity by large, expendable rocket engines. Such a conventional spacecraft would have to decelerate both for landing at Mars and on the

Placing a Starport (center) at space station Freedom would provide a low-Earth-orbit facility for staging missions to the moon and Mars via the Cycler system.

Space Exploration Schedule

1996: Construction of space station Freedom and its Starport begins

1997: First space taxi launches from Earth

1999: Starport complete and in use as taxi base; first lunar landing with taxi

2002: Assemble lunar Starport in low lunar orbit

2004: Develop and use advanced taxis and landers

2005: Transfer lunar Starport to L-2; develop lunar propellants

2006: Test Mars Starport

2007: Transfer Mars Starport to Mars orbit

2009: First manned mission to Mars orbit via non-cycling taxi spacecraft that will henceforth be used as the Semi-Cycler; complete Starport assembly, explore Phobos

2010: First Mars crew reassembles Semi-Cycler for their return to Earth. Second crew tests Cycler at L-2

2011: Cycler departs with manned taxi convoy; complete assembly enroute

2012: Mars lander arrives at Mars orbit as cargo. First Mars landing on this second manned Mars mission; second mission crew returns to Earth

2013: Next Cycler intercept; work on Mars surface base begins on third mission.

2014: Third mission crew returns to Earth

2015: Fourth mission crew departs for Mars on Cycler; a new second Cycler (for speedier returns) leaves L-2 unmanned

2016: Produce propellants at Mars surface base

2017: Crew intercepts second Cycler on its return to Earth; completes assembly of Cycler enroute

return to Earth, requiring a large expenditure of propellant or the use of an atmospheric aerobrake shield.

To optimize use of the heavy aerobraking equipment, the crew and cargo—including Mars landers—would have to be lumped together on a single jumbo vehicle. When prudent equipment redundancies are added to propellant loads, a manned Mars vehicle would weigh thousands of tons, as compared with the Apollo moonship's 40 tons.

Furthermore, no matter how massive these traditional spacecraft are at the outset of the voyage, they must shed their valuable modular stages in order to dump mass and lessen the amount of propellant needed for braking, making them too expensive for sustained Earth-Mars transportation. If we rely on conventional multi-stage spacecraft, we risk limiting human exploration of Mars to a few expensive "footprints and flagpoles" expeditions.

I believe there's a better approach. Several years ago, Tom Paine, the chairman of the National Commission on Space, encouraged me to expand my investigations into the use of spacecraft that would permanently cycle between the orbits of Earth and Mars. The results of these studies were included in the commission's 1986 report, *Pioneering the Space Frontier.* Such cycling spacecraft, one for manned outbound journeys and another for manned return trips, would use gravity assists from flybys of the planets to boost them along their orbits.

The major advantage of this approach is that it involves reusable spacecraft, which I call "Cyclers," on continuous gravity-assisted trajectories. These spacecraft, with their massive crew support equipment, no longer have to accelerate and decelerate off and onto planets because they continuously cycle along their orbits.

With the support of the Jet Propulsion Laboratory in Pasadena, California, I developed a family of Cycler trajectories which take advantage of recurring planetary encounters to permit travel between Earth and Mars with dependable regularity. Since then I have expanded cycling concepts into a blueprint for a relatively inexpensive and reusable Mars transportation system, which includes a family of permanent orbital staging facilities I call "Starports" and a series of smaller spacecraft to taxi crew members to and from these spacecraft and the planets.

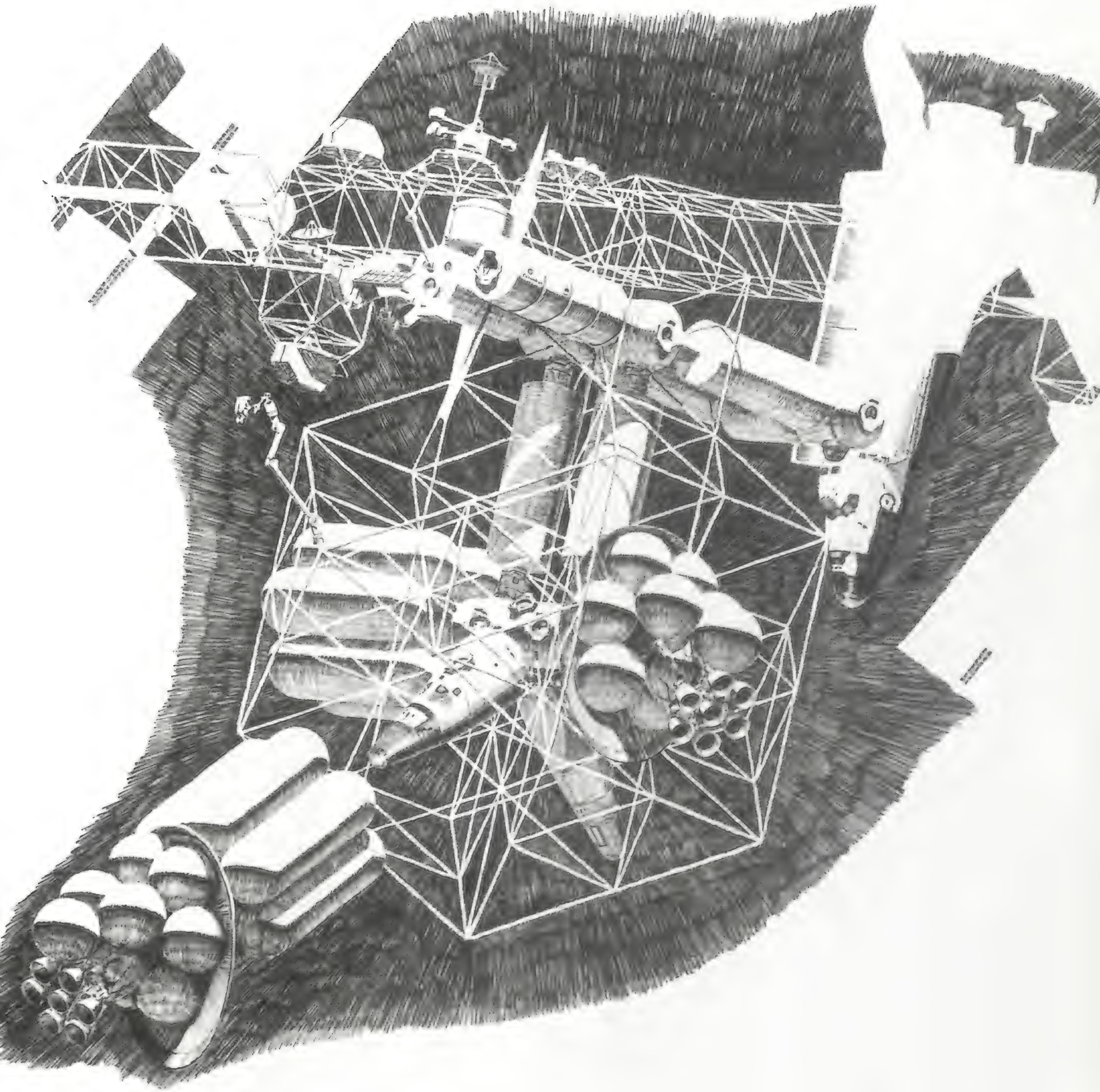
The mechanics governing the cycling orbits are both beautifully simple and dauntingly complex. Earth and Mars occupy nearly circular orbits. An Earth year, or revolution around the sun, is approximately 365 days, while a Mars year takes 687 days. With the Earth orbiting nearly twice as fast as Mars, a complete alignment of the two planets with the sun occurs every 26 months, or in just a bit more than two Earth years.

To bridge the gap between the two planets' orbits, a cycling spacecraft could be launched on a modified elliptical orbit, coming close enough to Earth or Mars to use the planet's gravity to bend its trajectory. On the next high-speed flyby of the other planet, this gravitational slingshot effect would be repeated. Eventually, the Cycler's elliptical orbit would rotate back to its starting place, which it would continue to reach at regular 26-month intervals. This permanent cycling trajectory would need only minor course corrections.

Like a ship sailing the trade winds, a cycling spacecraft would not follow a linear route between Earth and Mars. When the planets are aligned, the spacecraft would accelerate away from Earth and then loop outward, swinging close to Mars about five months later. But instead of expending propellant or using atmospheric drag to brake into Mars' orbit or to land, the Cycler would discharge smaller manned vehicles and a cargo pod. Then the Cycler itself would glide majestically on, using the boost of Mars' gravity to curve outward for eight more months, reaching its maximum distance from the sun before swinging back toward Earth. This unmanned return trip from Mars would take 21 months. In a sense, the vehicle would become a permanent, man-made companion of Earth and Mars, sharing with the asteroids and comets the free and inexhaustible fuel supply of gravity to maintain its orbit.

The simplicity of gravity-assist trajectories has already been demonstrated on a smaller scale by the unparalleled success of the unmanned Voyager 2 spacecraft, which used the slingshot assist of Jupiter to accelerate onto a trajectory that led it past Uranus and Neptune. Presently, the Galileo probe is completing a multi-pass Venus-Earth-Earth gravity-assist acceleration to loop it out to the orbit of Jupiter.

However, the discovery of convenient gravity-assist routes linking Earth and Mars—like the knowledge of the trade winds—is useless, arcane data unless we use ingenuity to develop practical hardware to exploit the potential of the Cycler. We need a Space Age caravel to ply the solar system's gravity ocean.



As with the other Starports in the Cycler system, the low-Earth-orbit facility would contain a central pressurized command module surrounded by berthing ports for small transfer taxis and propulsion stages.

To Mars and Back With the Cycler System

1) Riding in two or three small transport "taxis," the crew leaves the low-Earth-orbit Starport. They enter a staging orbit around Earth that positions them properly relative to the Cycler. These vehicles rendezvous and mate with refueled propulsion stages from L-2.

2) One to three days after leaving the staging orbit, the convoy of vehicles intercepts the Cycler and begins the five-month trip to Mars.

3) About two months before the Cycler encounters Mars, the propulsion stages for the return trip depart for the orbiting Mars Starport, timed to arrive safely ahead of the crew.

4) Shortly before encountering Mars, the crew leaves the Cycler in their taxis for a one- to three-day journey to aerobrake into Mars' atmosphere and then rendezvous with the Mars Starport.

5) The unmanned Cycler continues on a 21-month loop back to Earth.

6) The crew arrives at the Mars Starport, which serves as a permanent facility for servicing and dispatching landers for the exploration of Mars and its moons.

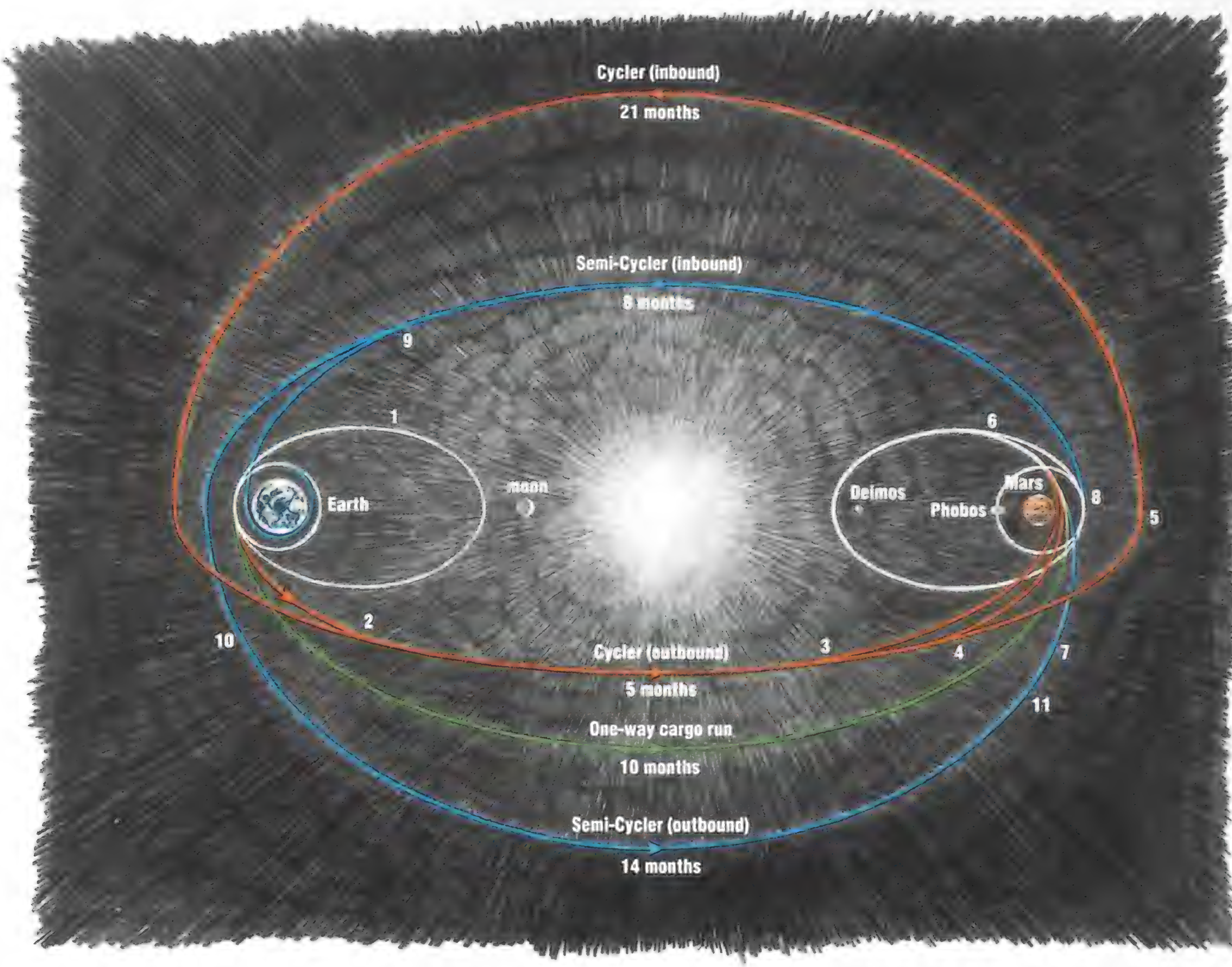
7) The Semi-Cycler, returning on the Earth-to-Mars leg of its journey, aerobrakes into Mars orbit about 16 months after the crew's arrival at Mars and four months before their departure.

8) To begin their eight-month trip back to the vicinity of Earth, the crew mates their taxis and three propulsion stages to the Semi-Cycler and thrusts away from the Mars Starport.

9) Just prior to encountering Earth, the crew taxis and propulsion stages separate from the Semi-Cycler and head for the LEO Starport.

10) The unmanned Semi-Cycler continues on, making a 14-month return to Mars.

11) The Semi-Cycler aerobrakes for recovery at the Mars Starport for use by the next mission's crew, and the cycle continues.



How would the Mars Cycler system work on this practical level?

Once we accept the Cycler principle, the fundamental support structure for Mars missions changes. The most massive components of this system are no longer repeatedly accelerated and decelerated—or discarded. Regular, predictable planetary flybys, not "planetfalls," become paramount. The Cycler system in effect creates an entirely new economic and philosophic approach to the Mars mission.

As would be impossible with a single massive spacecraft, the transportation requirements of crew and cargo would be separated, with the cargo traveling independent of the crew, who would ride in small, relatively low-mass "taxis" that join and depart the Cycler. Therefore, these manned vehicles must have permanent ports of departure and arrival orbiting Earth, the moon, and Mars.

We could begin by modifying the proposed U.S. space station Freedom to include a Starport vehicle processing facility. The design I like for this LEO Starport, as well as for those facilities that will orbit the moon and Mars and for the cycling spacecraft itelf, is an octo-tetrahedron, an adaptation of the system of construction devised by Buckminster Fuller, the innovative engineer and architect who developed the geodesic dome.

Built of lightweight but super-strong composite material beams, this first Starport would be attached to the space station's keel. The facility would consist of six concave pyramidal berthing ports, separated by eight tetrahedrons, all connected at the apex to a central pressurized command module with multiple ports. Some berthing ports could be enclosed for protection from heat and meteorites.

Highly flexible in design, the Starport would provide a single facility for translunar vehicle assembly, repair, checkout, and refueling. All these operations would be supported from the pressurized central command module. The Starport's modular construction also allows for easy expansion.

The Starport that would orbit the moon would provide storage, maintenance, and refueling capability at a single facility with a central manned habitat-workshop. During the initial phases of a moonbase buildup, this Starport could be kept in low lunar orbit. During this time, we could also test artificial gravity principles on the Starport by using centrifugal rotation (see "Life Beyond Gravity," December 1989/January 1990), a technique that could be adapted for the Mars Starport and the Cycler itself.

Later, the lunar Starport could be boosted out to the L-2 libration point, one of five such points in the Earth-moon system (L-2 is on the far side of the moon) where the planets' gravitational fields coalesce to form a neutral zone. Objects can remain in a stable orbit at L-2 without significant expenditure of energy. Positioned there, the lunar Starport could serve both as a support base for moon surface operations and as the "staging port" for crew and cargo about to embark on a Cycler mission to Mars.

During this period, vehicles used for lunar landing and orbital transfer and sharing a common basic design would be adapted for service as Mars landers and as taxis connecting the Starports and the Cycler.

Before we send humans to Mars, a Martian Starport, based on similar structural concepts, could also be assembled and tested at L-2. Then, using recoverable propellant stages, the unmanned Martian Starport could be dispatched to Mars, perhaps in several packages, and placed in orbit, through the use of either propulsion or by aerobraking, near the Martian moon Phobos. Since the cargo would travel independent of a crew, these freight runs could be low-velocity, low-propellant, 10-month cruises that take advantage of favorable planetary alignments. Following the placement of an automated plant on Phobos to convert surface material into propellant, the stage would be set for the Cycler's first manned voyage.

Because the function of the Cycler is essentially similar to the functions of the LEO, Lunar, and Mars Starports, the Cycler's configuration would be a direct outgrowth of these facilities. The Cycler's core would be an adaptation of the octo-tetrahedron radiating out from a central command module.

But the special requirements of deep-space, long-duration missions would dictate unique features for the huge vehicle. Artificial gravity would be needed because the Cycler would carry crews on voyages lasting many months. Also, because the Cycler would operate far from the sun, it could use a nuclear power plant, rather than the Starports' solar power cells.

These special requirements actually complement each other. I've designed a three-component Cycler consisting of a central Starport hub, a habitation module shielded from solar flares by a "storm shelter" of water tanks, and a nuclear power plant. Like beads on a necklace, these three components would

be connected by long, multi-cable tethers. The entire assembly could be spun up to rotate around the core of the Starport, the centrifugal force simulating gravity in the two end "beads." Adjusting the length of the tethers would vary the amount of gravity, from zero G in a compressed configuration to 1 Martian G (about a third of Earth gravity) when the spacecraft is elongated. Incidentally, the Mars Starport could also evolve into this standard three-component configuration and be spun up to create artificial gravity.

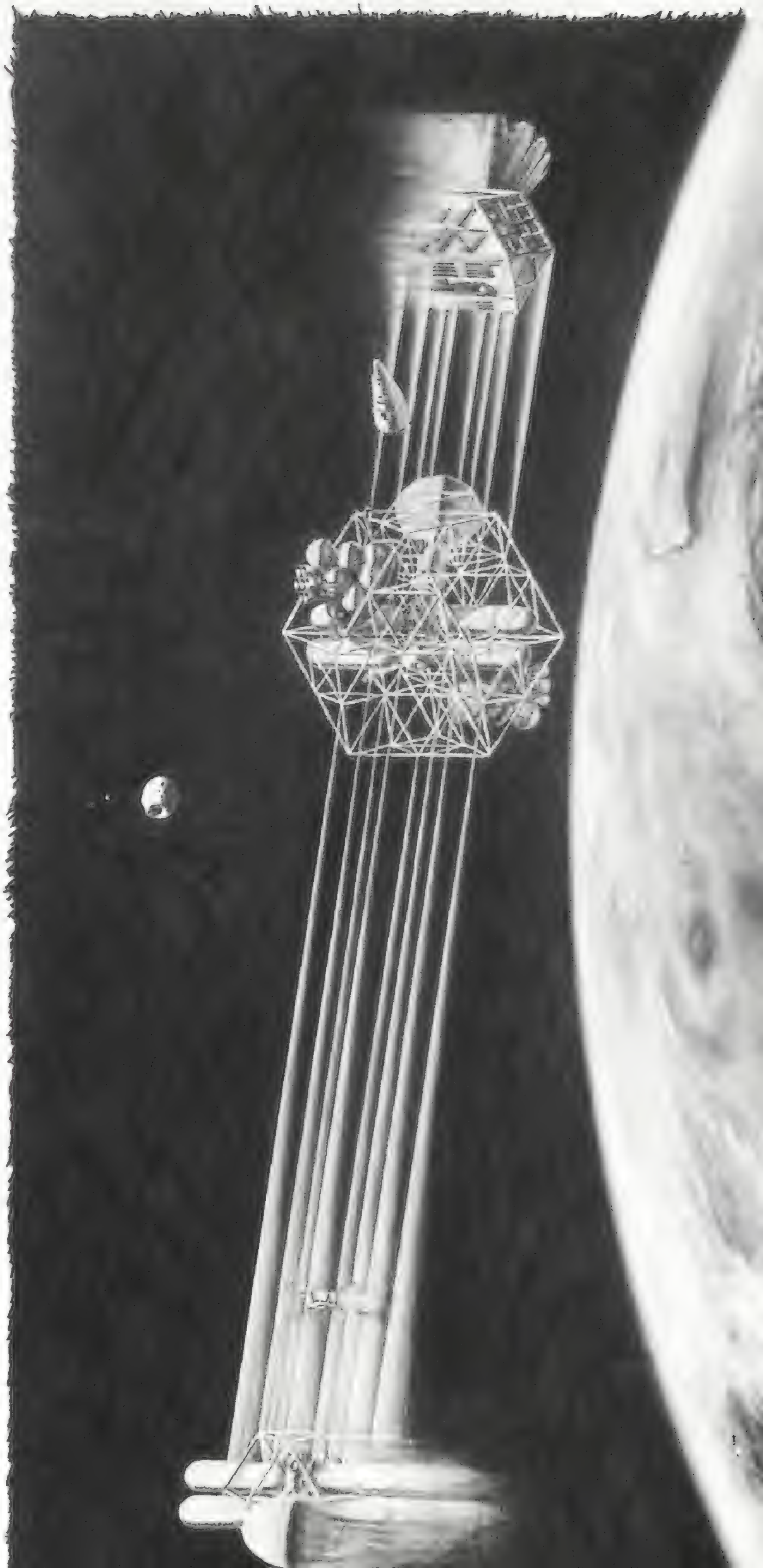
The Cycler would be propelled away from the Starport at L-2 onto its trajectory in a compressed configuration, using a recoverable propulsion stage that would loop back to L-2. The three components would then deploy along their tether bridle and spin up to produce artificial gravity. On this first run, the Cycler would be intercepted after leaving L-2 by a convoy of two crew taxis, a cargo pod, and their three propellant stages. On later missions, crews could depart for the Cycler from either the L-2 or the LEO Starport.

The crew would spend the five-month outward leg putting the Cycler's systems through their paces and verifying that the taxis were ready for deployment to Mars orbit. If serious glitches arose, the crew could simply sit tight and abort, riding the Cycler back to the vicinity of Earth on the 21-month gravity-assisted free return.

This automatic abort-to-Earth capability is one of the Cycler's prime attractions. A propulsion malfunction outbound would not doom the crew. Naturally, the Cycler would have life support provisions to sustain the crew for the full 26 months of the cycle.

Assuming all systems are up and running, about two months after departing Earth the Cycler's Mars crew would dispatch the propulsion stages ahead to the Mars Starport. After verifying the propulsion stages' safe arrival, the crew would then depart the Cycler just before its high-speed encounter with the planet, riding their taxi transfer vehicles to the Martian Starport, where they would take up housekeeping.

Exploratory excursions to the Red Planet's surface—via landers that would arrive at the Starport on separate cargo flights following the crew's arrival—could evolve in a conservative, progressive manner, executed by successive teams of crews safely based in their Mars Starport. One fundamental difference between this approach and conventional missions is the security of the permanent Mars Starport, an outpost from which rescue craft could be dispatched if

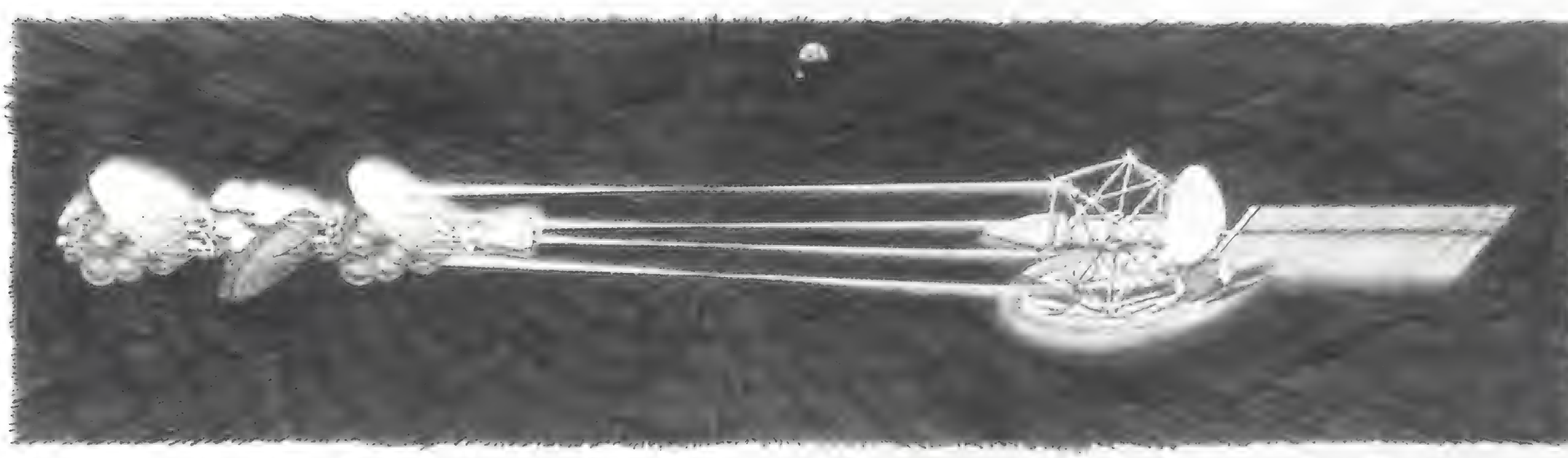


needed by surface explorers. This Starport also provides an excellent vantage point above the planet from which scientists can control a variety of unmanned robotic equipment on the surface.

For their return flight to Earth, a Mars crew would leave the Starport in a modular vehicle I call the "Semi-Cycler," consisting of a habitat module (dispatched, like the Mars landers, on a separate cargo flight) plus the transfer taxis and multiple propulsion stages.

The Semi-Cycler is necessary because the Cycler intercepts Mars at high velocity and quickly continues onward. The Semi-Cycler, so called because it would not cycle continuously between planets like the Cycler, would interrupt its cycle with a four-month aerobraked pause at Mars. The increased flexibility of departure times, coupled with the spacecraft's low velocity, makes the Semi-Cycler a more forgiving vehicle for the manned inbound trip.

Like the Cycler vehicle itself, the three-component Mars Starport (left) would spin around its central space hangar hub on long cable tethers, creating artificial gravity in the two end units.



With a transfer taxi and three propulsion stages on one end and a habitat module and taxi on the other, the Semi-Cycler would return crews from the Mars Starport to one near Earth.

When the Semi-Cycler neared Earth after an eight-month journey, the crew would depart for the LEO Starport aboard the taxis, along with their three propulsion stages. The vacated return vehicle would then use a gravity assist from Earth to accelerate back out toward Mars, a 14-month voyage. (If the module had problems, however, it could easily abort into the Earth-moon system along with the taxis.) This unmanned Semi-Cycler would aerobrake back into Mars orbit to pick up another returning crew.

Compared with conventional vehicles, which need to accelerate out of Earth's deep gravity well, repeatedly abandoning valuable engine stages, the Semi-Cycler is much more efficient in terms of propellant expended and reusable hardware.

Once this outbound/inbound Cycler system was established, crews could commute relatively quickly between the Earth-moon system and Mars, with the outbound leg taking five months and the return taking eight. Minor course corrections would be required, and propulsive energy would have to be periodically added to the composite vehicle to maintain its precise orbit. Fuel tanks for these maneuvers would join the Cycler as it passes the Earth.

As the Cycler and Starports mature, they would develop a closed-ecology artificial biosphere in order to remain independent from Earth for years. Like an oceanliner on a regular trade route, the Cycler would glide perpetually along its beautifully predictable orbit, arriving and departing with clock-like regularity. By plying the solar system's gravitational "trade winds" it will carry mankind on the next great age of exploration.

If we follow this evolutionary development track, instead of wasteful sprint approaches using either nuclear-propelled or massive conventional spacecraft, the United States and its international partners will easily be able to afford this system of Cyclers and Starports. For roughly the same cost as getting humans safely to Mars via conventional *expendable* rocketry (because the problems to be solved would be largely the same), the Cycler system would provide a *reusable* infrastructure for travel between the Earth and Mars far into the future. As the National Academy of Sciences' National Research Council notes, the exact cost of manned solar system exploration is almost impossible to predict. But the council also calculates that an evolutionary approach—such as the Cycler system—can be undertaken for a few tenths of a percent of our gross national product. Of course, such public expenditures must be justifiable. My Cycler system offers mankind a permanent bridge between the planets, to be expanded and exploited by future generations, just as our predecessors exploited the trade wind routes blazed by Vasco da Gama and Christopher Columbus.

When Geoff was just a kid, AT&T was just the phone company.

Today AT&T has spawned a whole new generation of computer and communications technologies.

AT&T Fax

For Geoff, a freelance architect, AT&T made it easy for him to work at home. His most indispensable items? A mechanical pencil and his fax machine.

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The right choice.

Treasures of the Air and Space Museum

Text by Tom Huntington

Photographs by Carolyn Russo and Mark Avino (NASM)

AIR&SPACE
Smithsonian

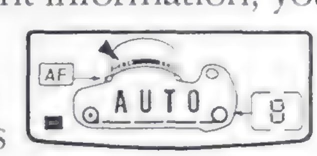
CATCH A CAT NAP WITH OUR NEW PROCES METERING SYSTEM.

The house jutted out from the sea and every winter it had been sealed with spray from the white-caps. Forgotten furniture lay silent, cloaked in folds of canvas. And as a rush of light invaded the interior, a mass of fur curled into a familiar warmth. The rest is photography. The Pentax art of photography.

This is a moment that fuses the intricacies of light and pure emotion. It's a moment that demands a camera capable of responding accurately and dramatically to the situation without altering the mood. That camera is the Pentax SF10 equipped with a system called PROCES metering.

Imagine your subject against severe backlighting. To avoid under or overexposure our PROCES metering system automatically compensates by taking separate readings from the background as well as the center of the frame, resulting in a pure sharp image.

Combined with the SF10's CENTIC Panel which relays all relevant information, you can see why this camera is considered user friendly.



The SF10 is a unique means to a creative end. It comes equipped with such features as Auto Focusing, Auto Exposure and a Built-in Retractable TTL Auto Flash. And for more information see your local Pentax dealer.

PENTAX SF10

Photo by Kevin Logan

Ektar 25. The genius is in the details.

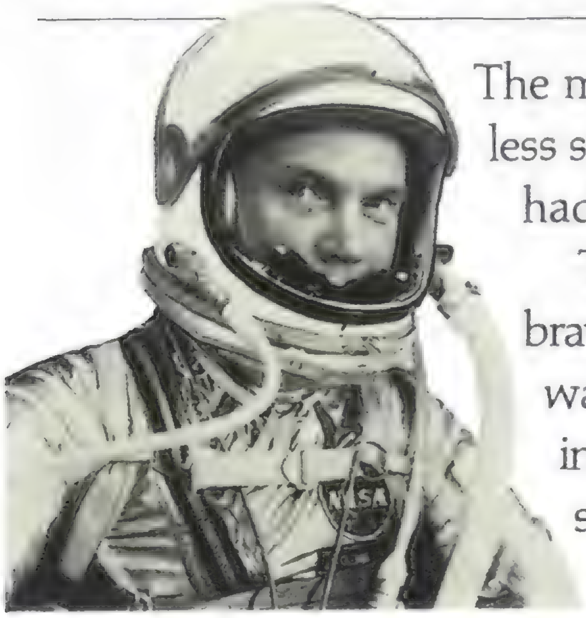
For the flight enthusiast, the National Air and Space Museum is heaven on Earth. Push open the doors from the Mall in Washington, D.C., and you'll find yourself face to face with the Wright *Flyer* (below), the first airplane to take wing (Orville was flying; Wilbur was standing, arms cocked, by the wing as the frail machine lifted off its tracks). Above and behind the *Flyer* is a small, high-winged silver monoplane. The name lettered on its metal-sheathed nose: *Spirit of St. Louis.* In this tiny airplane young Charles Lindbergh made a daring flight across the Atlantic that awakened much of the world to the potential of air travel. Below and behind the *Flyer* rests the Apollo 11 capsule *Columbia.* Sixty-six years after the Wrights' first success, this tiny, cramped cone took the three Apollo 11 astronauts a quarter of a million miles to lunar orbit. From there, Neil Armstrong and Buzz Aldrin made the final perilous descent and became the first human beings to visit another world.

And that's just the beginning of the treasures to be found at the National Air and Space Museum.

The Smithsonian Institution was established by an act of Congress in 1846 but didn't acquire its first aeronautical artifacts until 30 years later, when the Imperial Chinese government donated a set of kites. The Museum still has them; they can be found at the Paul E. Garber Preservation, Restoration and Storage Facility outside Washington.

On August 12, 1946, Congress established the National Air Museum. Its charter: "to memorialize the national development of aviation; collect, preserve, and display aeronautical equipment of historical interest and significance; serve as a repository for scientific equipment and data pertaining to the development of aviation; and provide educational material for the historical study of aviation." Space was added to the charter 20 years later.

THEY SAY IT'S GOING TO FLY. OF COURSE, THEY AREN'T GOING.



On February 20, 1962, the Atlas of Friendship 7 boosted the first American, John Glenn, into Earth orbit. His historic flight was the 117th for an Atlas.

The machine had stainless steel skin. The men had steel nerves.

The men were the brave Americans who waited, strapped into a cramped capsule atop 125 tons of explosive fuel, to be blasted into orbit.

The machine was originally America's first intercontinental ballistic missile, developed by General Dynamics in the early 1950s, and for nearly 10 years the free world's major deterrent weapon.

The men were the Mercury astronauts.

The machine was our Atlas rocket.

Their histories merged in the early 1960s, when General Dynamics began reconfiguring Atlas to launch payloads into space for the Air Force and NASA.

Since then, the stainless steel sheen of the Atlas skin is the only thing that has remained unchanged, as literally thousands of technological improvements have been incorporated.

This fiendish-looking device was part of the apparatus we built to simulate effects of weightlessness. In addition to training equipment, General Dynamics also built tracking stations around the globe.

Atlas has boosted virtually every U.S. weather satellite. In December 1958, it boosted the world's first communications satellite, Project Score, which circled the globe broadcasting President Eisenhower's Christmas message. Atlas went on to launch 36 more communications satellites, and dozens of scientific probes, including Pioneer, Mariner, and Surveyor, the first American spacecraft to soft-land on the moon.

With a record of 496 launches, our Atlas is one of America's most successful and reliable launch systems.

A new downtown building (above) was opened on July 1, 1976. In the years since, the Museum has become one of the most popular in the world. More than 100 million people have walked through NASM's doors, and they continue to visit at an average rate of eight million people a year.

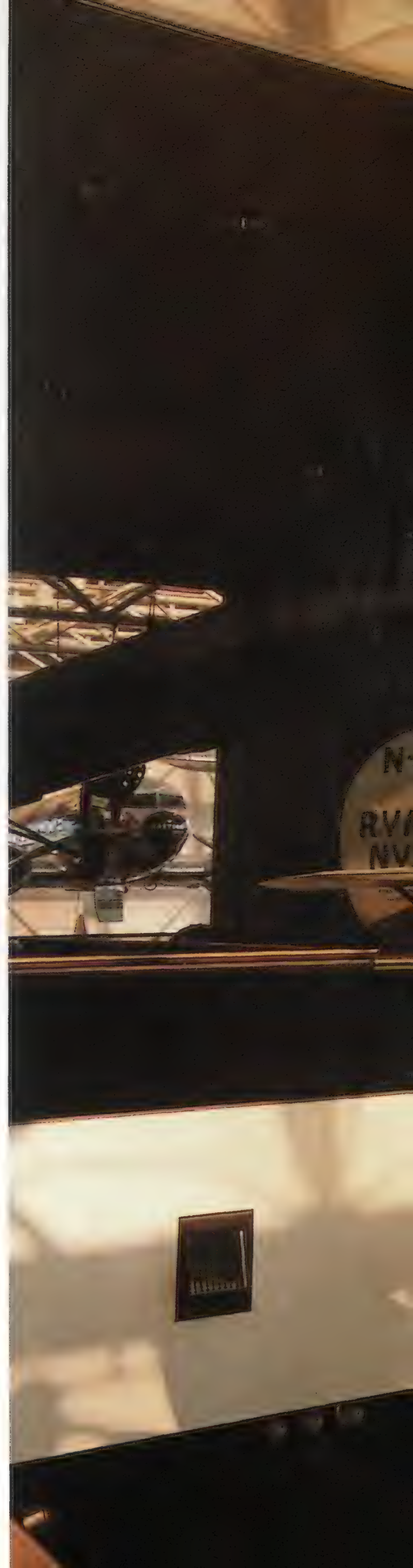
For many visitors, the artifacts in the Museum are memories made real. The sight of *Friendship 7* may evoke the excitement of the day when John Glenn orbited the Earth and put the United States back in the "space race." For some, the shining silver DC-3 in the Hall of Air Transportation is a reminder of the roar of its twin engines during a long-ago flight.

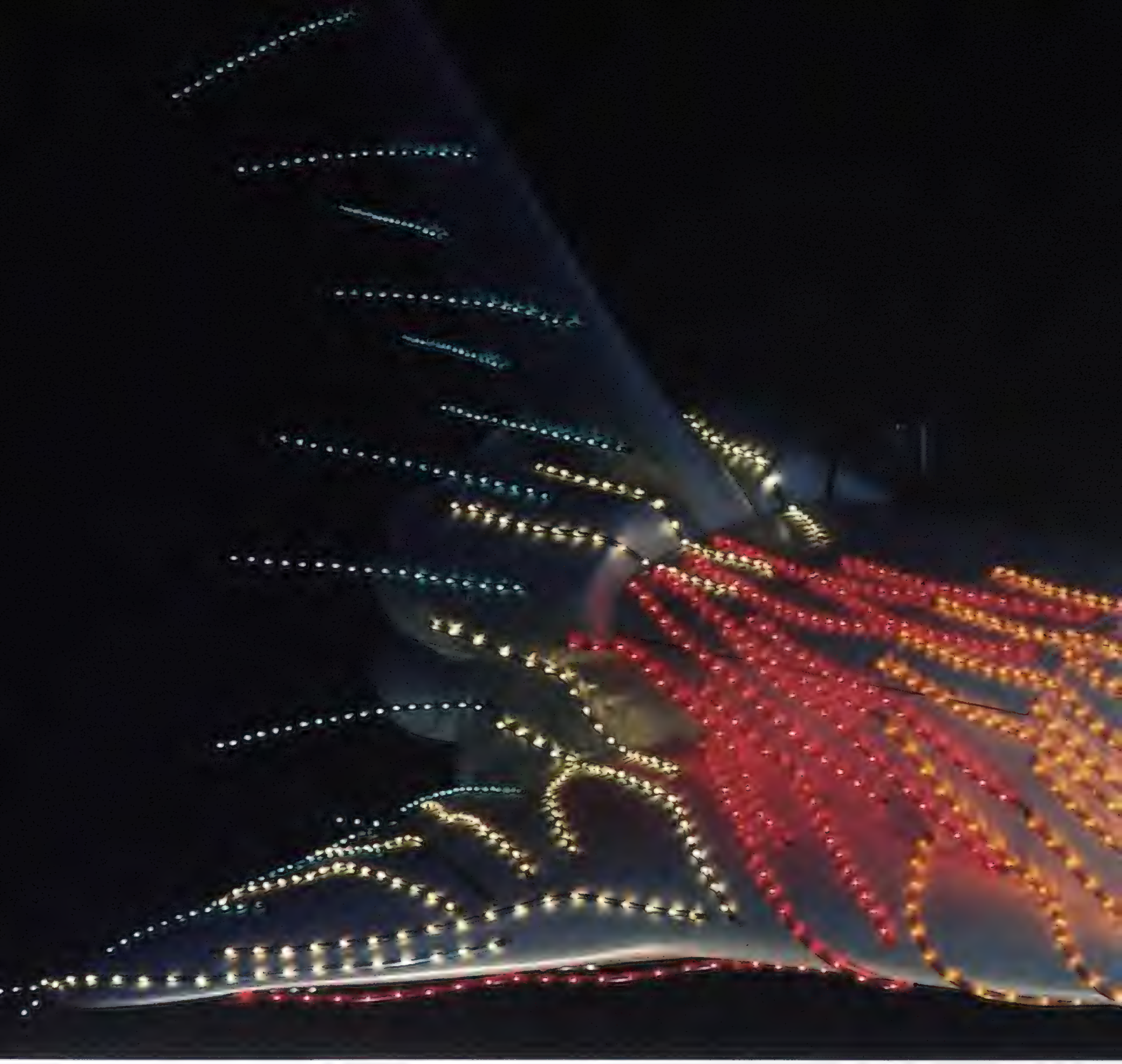
The artifacts in the Museum conjure up more than the movement of pistons and the roar of jets. They have stories to tell: stories of courage, ingenuity, and endurance, and sometimes stories of horror. They may reflect the slow, steady experimentation of the Wright brothers; the eccentricities of wealthy industrialist Howard Hughes, who was determined to build the world's fastest airplane—and did; the accomplishments of Wiley Post, the one-eyed pilot of the *Winnie Mae*; or the tragedy of a world plunged into war.

Advancements in aerospace have profoundly changed the world. Airplanes have revolutionized the way we travel; airplanes and missiles have changed the way we wage war and keep peace. Satellites have transformed communications and, through surveillance, perhaps help us prevent war. And after the boosters designed to hurl nuclear warheads at our enemies instead sent people into space, humankind has taken its first tentative steps off the planet. This perspective has given us new insight into our Earth and an increased awareness of the opportunities—and dangers—that we face in the future.

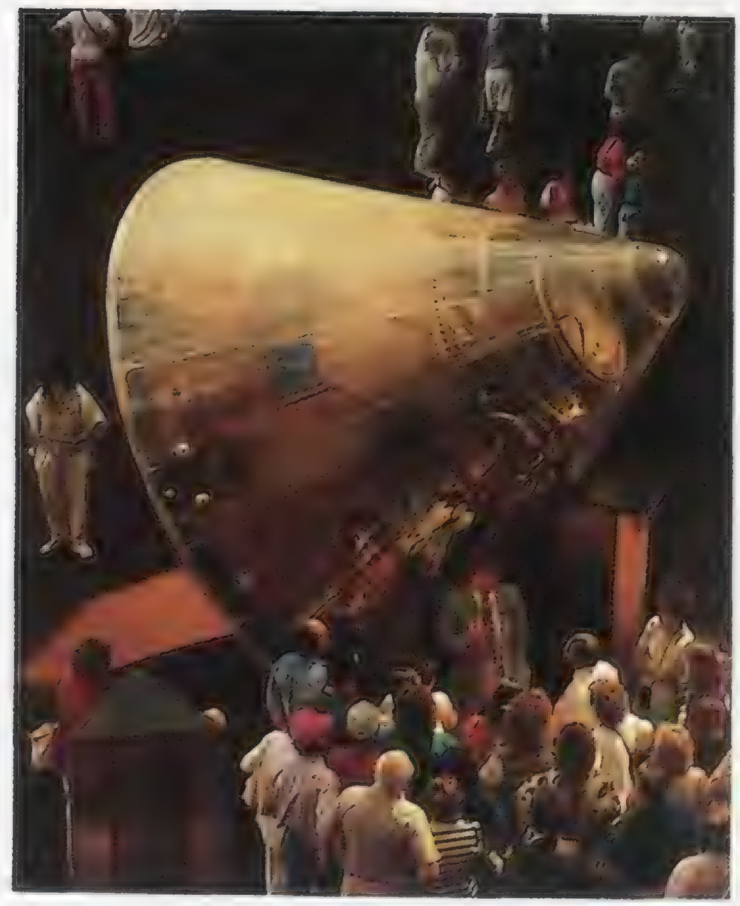
The SPIRIT OF ST. LOUIS and the Bell X-1, two of the aircraft in the Milestones of Flight Hall, are renowned for breaking barriers (right). Charles Lindbergh used the SPIRIT in 1927 to make the first nonstop flight between New York and Paris (also the first solo nonstop flight across the Atlantic). Twenty years later, Chuck Yeager broke the sound barrier in the X-1.

Marking a milestone of another kind, the Soviet SS-20 and U.S. Pershing II missiles (left) symbolize the destruction of an entire class of nuclear weapons, the result of the Intermediate-range Nuclear Forces (INF) treaty.





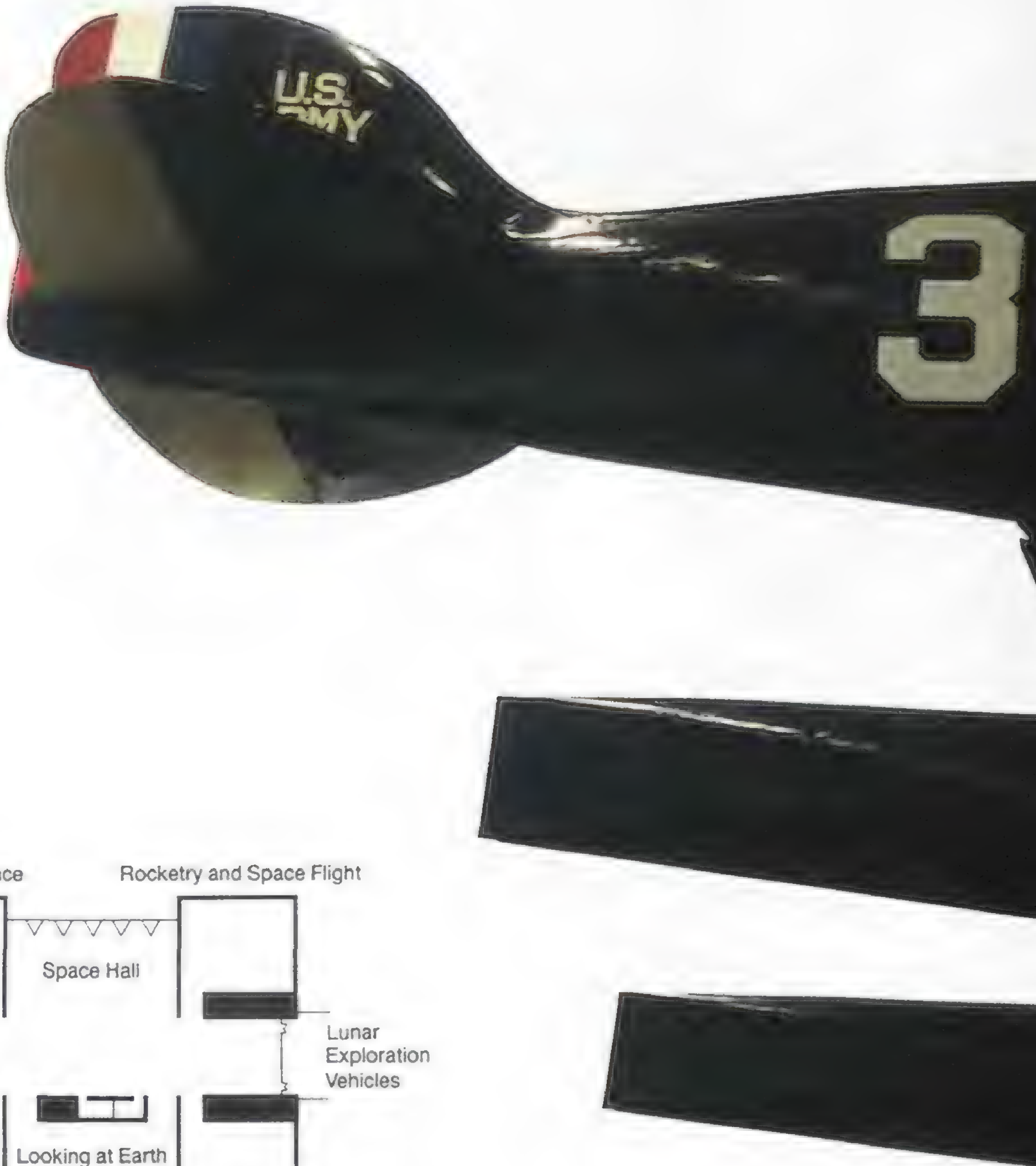
Trails of light mark the airflow over a model of a space shuttle in the Beyond the Limits gallery, which is focused on how computers have changed the art of design (top). Inside the Museum's Albert Einstein Planetarium, the Zeiss projector can create our entire galaxy within the confines of a domed ceiling (right).



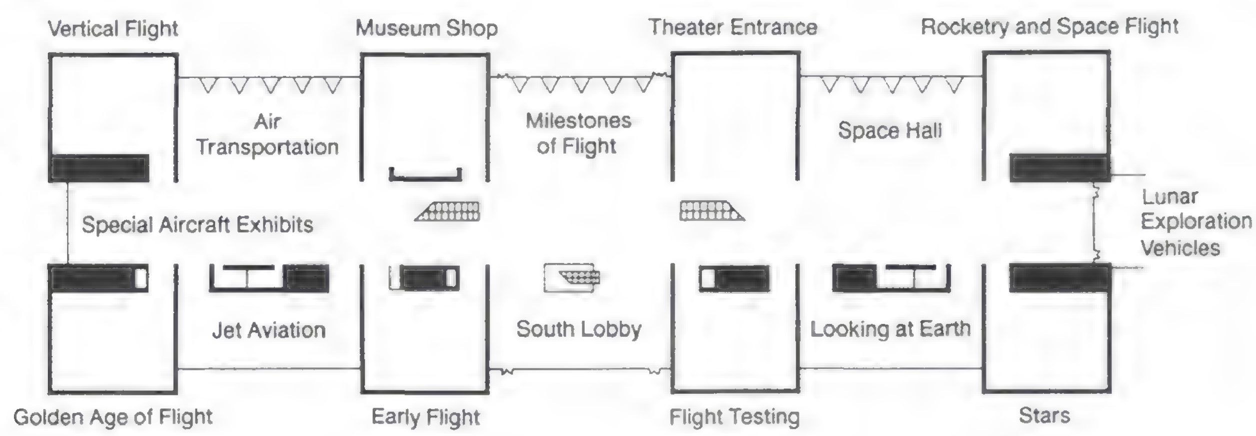
When Apollo 11 thundered aloft from Florida on July 16, 1969, carrying Neil Armstrong, Buzz Aldrin, and Michael Collins, the Saturn V rocket stood 363 feet tall. When the Apollo returned to Earth, after Armstrong and Aldrin had walked on the moon, all that remained of the rocket was the capsule COLUMBIA *(above). The helicopters in the Vertical Flight gallery represent a number of technical breakthroughs, from Igor Sikorsky's pioneering XR-4 to the Bell 206L-1 named* SPIRIT OF TEXAS, *the first helicopter to fly around the world (left).*

Few stop to realize it, but humans were flying 120 years before the Wright brothers' success at Kitty Hawk. In 1783 another pair of brothers, the Montgolfiers, built a balloon in which Jean-François Pilâtre de Rozier and the Marquis d'Arlandes became the first humans to venture into the air. A large model of the balloon (just behind the red and white model of one flown by J.A.C. Charles the same year) will soon be moved to the Milestones of Flight Hall.

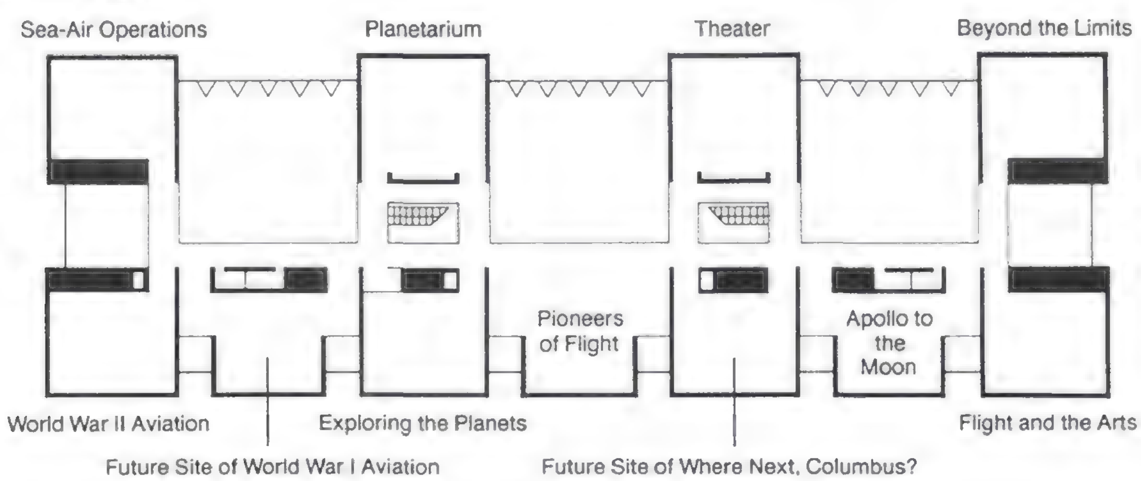
In 1924 four Douglas World Cruisers started on the first round-the-world flight. Two finished; the CHICAGO is in the Pioneers of Flight gallery (detail above).



First Floor



Second Floor



Originally housed on the Mall in a "temporary" building that had been constructed to test Liberty airplane engines during World War I, the National Air and Space Museum moved to its current location in 1976. Its 23 galleries include everything from early aircraft to modern space vehicles.

Competition—whether through figurative "space races" or the real kind—has often served to advance technology. That was never better demonstrated than in the Schneider Trophy races, contests fought by seaplanes that led to faster speeds and better engines. In 1925 Jimmy Doolittle won the trophy in the Curtiss R3C-2, now on display in the Pioneers of Flight gallery.

The Apollo-Soyuz Test Project of 1975 was the first international manned mission in space. Linked by an androgynous docking adaptor, the U.S. Apollo spacecraft (right) joined with the Soviet Soyuz vehicle (far right). The resulting "handshake in space" showed that superpower cooperation in space was possible. The full-size replica of the two spacecraft can be found in Space Hall.

In 1911 an Italian pilot in Northern Africa dropped hand grenades from his Blériot XI onto Turkish troops. In the process he became the first aviator to turn his airplane into a weapon. The airplane's role as an instrument of war grew dramatically during World War I, with airplanes being used first for reconnaissance, then as fighters, and finally as strategic bombers. By World War II the airplane had become a weapon with unprecedented destructive capability.

Two of the Museum's future exhibits will revolve around controversies about the airplane's use as a weapon. Following a complete redesign, a new World War I gallery will examine the airplane's deadly evolution during what was optimistically called "The War to End All Wars." (One of the aircraft on display will be a German Albatros D.Va—below—one of only two remaining in the world. It was in an Albatros that Manfred von Richthofen, better known as the Red Baron, scored most of his victories.)

The *Enola Gay* (right), the B-29 Superfortress that dropped the atomic bomb on Hiroshima, is now being restored at the Garber Facility. When the work is completed, the airplane will be displayed at the future Museum Extension at Washington-Dulles International Airport. There it will be the centerpiece of an exhibit examining the controversial issue of strategic bombing.

When the Japanese Zero first flashed across the sky in the late 1930s, it seemed unbeatable. Throughout World War II the Zero was Japan's front-line fighter, even though it was obsolete by war's end. The Museum's Zero is in the World War II gallery.

Outside the entrance to the World War II gallery hangs a shark-faced Curtiss P-40 Warhawk (below). The P-40 achieved its greatest fame as the airplane flown by the American Volunteer Group—the Flying Tigers.

Once upon a time, aircraft could be designed by the TLAR (That Looks About Right) method. Today supercomputers have replaced slide rules, as the new computer gallery, Beyond the Limits, demonstrates (right). Some modern aircraft, like the forward-swept-wing X-29 (a mockup of which is suspended in the rear of the gallery), would not be able to fly without computer control.

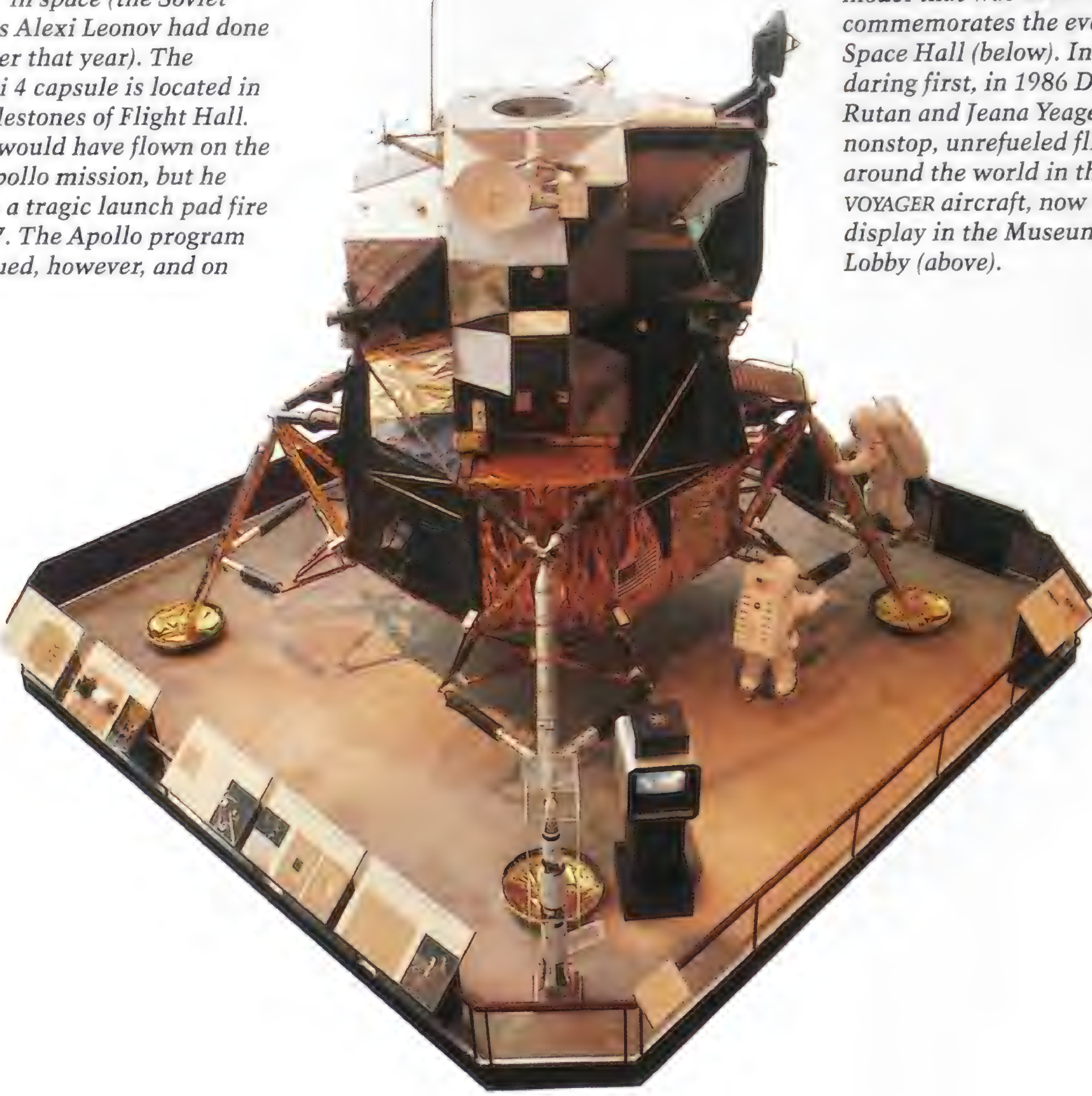
But most people become familiar with aerospace technology through peace, not war. Peaceful aviation flourished between the world wars, a time known as the Golden Age of Flight. During the Golden Age, remembered in its own gallery (above), the technology advanced by leaps and bounds and captured popular imagination. The gallery's centerpiece is Howard Hughes' H-1 racer, once the world's fastest airplane.

The golden airplane of commercial aviation, the Douglas DC-3 (opposite page, center), is suspended in the Hall of Air Transportation. One casualty of the DC-3's success was the Boeing 247 (an example hangs below the Douglas). Introduced in 1933, it was soon rendered obsolete by the DC-3. In the foreground is another legendary transport, the Ford Tri-Motor.

The business plane was another development from the Golden Age. Flight-ready visitors to the Museum study an example, the Grumman Goose on display in the Hall of Air Transportation (right).


EASTERN AIR LINES
FORD
TRI-MOTOR
DOUGLAS
DC 3

In 1965, astronaut Edward White stepped outside his Gemini 4 capsule (above) to become the first American to "walk" in space (the Soviet Union's Alexi Leonov had done it earlier that year). The Gemini 4 capsule is located in the Milestones of Flight Hall. White would have flown on the first Apollo mission, but he died in a tragic launch pad fire in 1967. The Apollo program continued, however, and on July 20, 1969, Neil Armstrong and Buzz Aldrin walked on the moon. The Museum's lunar module, an operational test model that was never used, commemorates the event in Space Hall (below). In another daring first, in 1986 Dick Rutan and Jeana Yeager flew a nonstop, unrefueled flight around the world in the VOYAGER *aircraft, now on display in the Museum's South Lobby (above).*

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In the 1990's, American defense contractors are facing a threat they never anticipated: the end of the Cold War.
This event is the best news in 45 years. It also presents a real opportunity to redefine our country's defense requirements.
To meet these changing requirements and reduce spending at the same time, defense contractors must apply cost-effective technologies. Technologies that will help reshape our military into a more flexible, versatile, efficient force. Grumman is at work on these technologies now.
We're developing an advanced "eye-in-the-sky" satellite system which can immediately detect a missile launch anywhere on the globe with technology that never blinks.
Technology has always been America's best defense. And Grumman has the technologies that make sense today.
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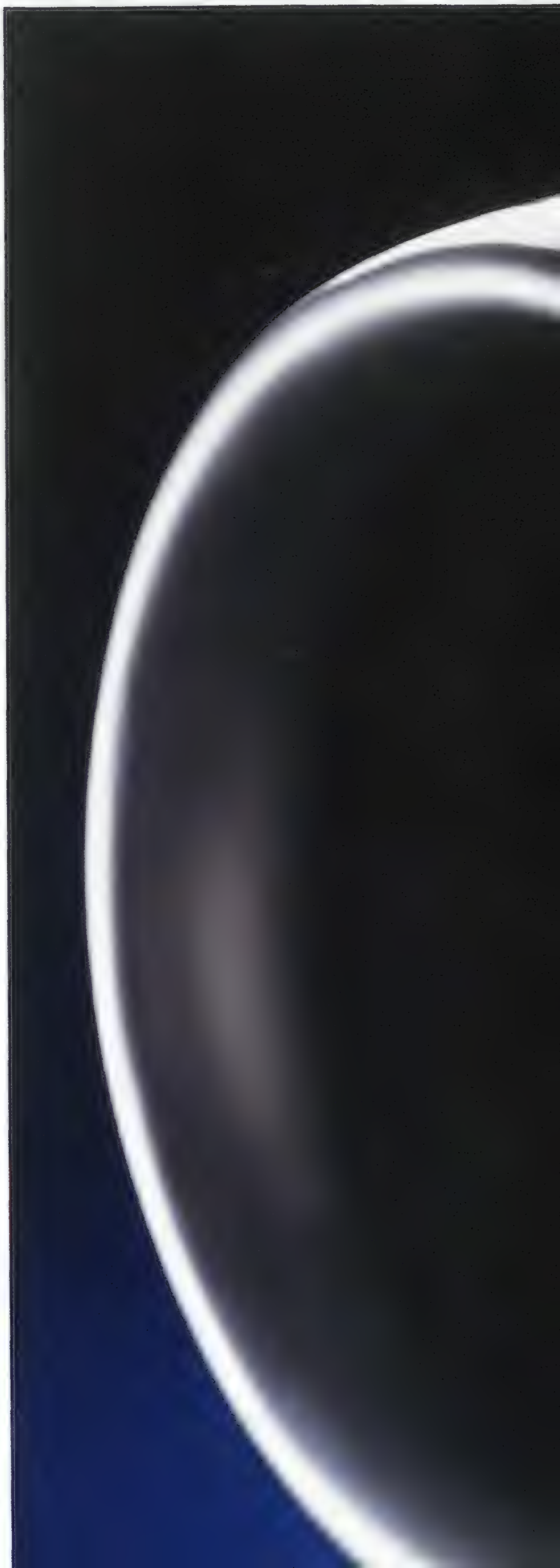

The aircraft and spacecraft on display at the Mall represent only a fraction of the Museum's total collection. Many more are in storage at the Garber Facility, and others are mothballed at Davis-Monthan Air Force Base in Arizona. There's also a growing collection in storage at Washington-Dulles International Airport in suburban Virginia, including a Lockheed Constellation (bottom) and an SR-71 Blackbird (middle). Future additions will include a Concorde and a Boeing 747—not exactly items you can stick away in a closet.

To find space for this growing collection, the Museum plans to construct an Extension at Dulles. Following Congressional authorization, the Smithsonian will begin an extensive fundraising capital campaign, seeking the support of individuals, corporations, foundations, and associations to make the dream of the Extension a reality.

It will be a big task. The Extension will be much larger than the current building, with a "footprint" of 27 acres. It will house the artifacts presently at the Garber facility. The Museum's restoration work will also be done at Dulles, in an area that will allow visitors to observe the process.

Airplanes on display will include the *Enola Gay* and the space shuttle proof-of-concept vehicle *Enterprise,* currently stored in a hangar at Dulles (above, with an F-4 Phantom). If all goes according to plan, the Extension will open in 1995, allowing the National Air and Space Museum to deliver on its charter's mandate well into the next century.


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Shuttle Pit Stop

As soon as a space shuttle
rolls to a stop,
8,000 technicians roll
up their sleeves.

by Greg Freiherr

Photographs by John Ricksen

In the pre-dawn darkness of California's Mojave Desert, the Orbiter Recovery Team huddles in front of an Airstream motor home loaded with sophisticated electronics. On a flip chart bathed in spotlights they review the procedures one last time for the task that is almost at hand. Three hundred miles above them and on the other side of the Earth, the crew of the space shuttle *Discovery,* which several days earlier had launched the Hubble Space Telescope, is preparing to somersault back home.

It is 4:30 a.m., April 29, 1990, on the dry lakebed of Edwards Air Force Base. As an assortment of vehicles rumbles across the desert, the *Discovery* crew prepares the winged spaceship for reentry. The recovery convoy will wait for the shuttle midway between the base's primary and alternate runways.

All together some 160 personnel are waiting here in the desert for *Discovery.* But they are only a fraction of the largest pit crew in the world. During the next five months more than 8,000 others will spend almost a million hours getting the world's only reusable manned space vehicle ready for its next launch.

The space shuttle was initially conceived as needing only two weeks of preparation between landing and

When a shuttle touches down at Edwards Air Force Base in California, a convoy of recovery vehicles rushes to meet it (left inset). While still in the desert, it undergoes preliminary safing procedures that include draining the propellants and purging the lines (inset right). Then it's a piggyback ride on the special 747 that returns the shuttles to the Kennedy Space Center in Florida, where they are readied for another launch.

NASA (2)

Daniel Miller, a quality assurance engineer, is one of thousands of contract employees who service the shuttles.

Upon its arrival at Kennedy, the shuttle is carefully removed from the 747 by the mate/demate device.

launch. That proved overly optimistic. The quickest turnaround so far occurred when *Atlantis* was readied in just under eight weeks after a 1985 flight. Since the resumption of shuttle flights following the *Challenger* explosion in January 1986, the fastest turnaround has been 18 weeks.

This year's shuttle manifest called for

Atlantis is towed to the Orbiter Processing Facility, where the shuttle will spend two-thirds of its time between launches.

a launch rate as high as the program had achieved just before the 1986 accident—nine per year, or one every five to six weeks. But last summer's problems with hydrogen fuel leaks briefly grounded the fleet after three launches. It also called the space shuttle's reliability into question.

It wasn't the first time. The *Challenger* investigation raised questions about whether the shuttle had been launched on an unseasonably cold day because of pressure to meet a schedule that was falling behind. In the post-*Challenger* era, NASA has stressed a new "safety over schedule" credo. Yet the pressures to get the shuttles back on the pad are always there.

"Sure there are timelines to meet," says Larry Ellis, deputy director of shuttle operations, about postflight operations. "I would call that pressure. It's a schedule . . . . [But] if we didn't have a plan laid out it would just take as long as it takes, and we may never get there."

Time is irrefutably a luxury, especially in the moments immediately following a landing. After *Discovery* touches down, the spacecraft continues to roll for about a minute. When it comes to a stop, mission responsibility shifts from Houston's control room to Florida's Kennedy Space Center and its workers in the California desert.

While the shuttle crew completes their post-landing check, recovery team members approach *Discovery* and use sensors to ensure that nothing toxic is leaking from the orbiter. In the event of propellant leaks, a truck with a large fan stands ready to blow away dangerous gases.

The ground crew has only 45 minutes to hook purge and coolant lines to the tail of the orbiter. If they are tardy, the boilers that cool the shuttle's electronics run out of ammonia coolant and the electronics have to be shut down before they overheat. This would delay the flight back to Kennedy.

On a mobile staircase parked behind *Discovery,* technicians Tom Gay and Billy McClure wrestle with the 12-inch-

The Piggyback Ride

The shuttle's tiles can deflect thousands of degrees of heat on reentry—but not raindrops. This vulnerability is one reason that the shuttle lands at Edwards Air Force Base in the California desert instead of Kennedy Space Center in Florida, with its unpredictable thunderstorms. Since the shuttle's landing site is so far from its ultimate destination, a modified Boeing 747 (100 series) is used to ferry the shuttle home.

The shuttle carrier aircraft, which orginally transported passengers for American Airlines, was purchased by NASA in 1974. "The 747 we've been flying is a very young airplane in hours, but it's very old in years," says Joe Algranti, chief of aircraft operations at the Johnson Space Center in Houston and the man in charge of seeing the shuttle safely back to Florida. "It's flown about 10,000 hours but it was built in 1970, so it's 20 years old."

The most obvious difference between NASA's shuttle ferry and your average 747 is the huge vertical aluminum plates, called tip fins, which are attached to the ends of the horizontal stabilizers at the tail and make up for the yaw control that is lost due to the added bulk of the shuttle sitting atop the airplane. Engineered by Boeing, the tip fins measure over 20 by eight feet and, from the ground, look like vertical billboards.

The shuttle is mated to the 747 at the same three ball-and-socket attach points that are used to secure it to the external tank during launch. Inside, the airplane has been stripped, and new bulkheads have been added to the attach points. The airplane's skin is doubled and tripled in several places. To maintain the 747's center-of-gravity limits, ballast is carried in its forward cargo compartments.

The shuttle-747 combo takes flight after rolling down two miles of runway. Its combined weight, including the mated spacecraft, any cargo in the shuttle's payload bay, and fuel, is just shy of 700,000 pounds. As the duo churns its way east, it's limited to 290 mph (.6 Mach) due to the vibration induced on the 747's tail by the airflow over the orbiter. The normal cruise altitude is 13,000 to 15,000 feet.

Because of the shuttle's aversion to rain, the shuttle carrier requires a pathfinder to sniff for clouds. "You got to have somebody out front checking the waters," says Algranti, who often flies in the front left seat of the airborne ferry. Consequently, NASA will fly only during the day, when clouds can be seen. Most recently the escort has been a C-141, which also carries a support team.

Two pilots and two flight engineers fly the Edwards-to-Florida-and-back run. First stop for refueling is usually Kelly Air Force Base in Texas. Flying with the shuttle on its back at low speeds and altitudes wreaks havoc with the 747's fuel economy, such as it is. Fuel burn is about 100 gallons per minute. In good weather the shuttle ferry service takes one or two days to get from Edwards to Kennedy.

A second 747 is now in Boeing's Wichita facility undergoing the last of the modifications it needs to fly with a shuttle on its shoulders. If the schedule holds, expect to see a second NASA shuttle ferry flying by the end of the year.

—David Almy

Processing the shuttles between missions takes place 24 hours a day, seven days a week.

diameter coolant hose. Suddenly the wind shifts and ammonia from the shuttle's boilers fills the air. To catch his breath, Gay has to step down from the staircase. "This isn't just household ammonia," he says. "This is 99 percent pure."

Gay and McClure normally work at Kennedy. To meet *Discovery* they have left work on *Columbia* and *Atlantis,* which are in different stages of the ground turnaround process. Here in the California desert they have to deal with wind gusts of 60 mph. Cars caught in these storms have had the paint blasted off them. For Gay and McClure, both used to the climate of the Sunshine State, these working conditions leave a lot to be desired. Gay succinctly sums up their feelings about the winds: "It's miserable."

During the next hour, other ground support equipment is connected to cool both the flight crew and the avionics while the recovery team readies the shuttle to leave the desert. Finally, their post-landing and systems checks complete, the *Discovery* crew—Loren Shriver, Charles Bolden, Steven Hawley, Bruce McCandless II, and Kathryn Sullivan—disembark down a staircase mounted on the back of the shuttle exit truck. This mission is over.

Almost a week later, after a flight back to Kennedy Space Center aboard NASA's modified 747 (see "The Piggyback Ride," previous page), *Discovery* has been jacked about 10 feet in the air and encased in a skeleton of work platforms, catwalks, and bridges in the Orbiter Processing Facility. This is where a shuttle spends two-thirds of its total processing time before launch. The facility's two identical hangars, which are connected by offices, labs, and storage areas, permit handling two orbiters simultaneously.

Processing the shuttle for a return to space requires 761,000 separate opera-

NASA operations engineer Jennifer Webb rides herd over contract workers in the Orbiter Processing Facility.

tions involving many of its 210,000 parts. Virtually every phase of the ground turnaround is monitored by a bank of 336 computers known as the Launch Processing System. Temperatures, pressures, flow rates, voltages, valve and switch positions—all are scrutinized millisecond to millisecond. Readings outside the norm trigger an immediate response from the computer, which alerts the nearest technician. "There are so many parameters that have to be within spec to launch the vehicle that it's—I don't want to say humanly impossible—but it would be just a hell of a chore for the system engineers to monitor all those parameters," explains Mike Leinbach, one of NASA's test directors. "Therefore it's all computerized."

But the pre-launch phase isn't a cookie-cutter process. Each mission leaves an orbiter in a different condition: brakes may be worn, tiles chipped, or oil slobbered in the payload bay from a broken hydraulic line.

When the shuttle returns to the Orbiter Processing Facility, the first task is to complete the "safing" operations begun in the desert—draining leftover propellants and purging the lines. "There are a lot of major operations that happen right away, like pulling out the engines," says Jennifer Webb, a NASA operations engineer who graduated with a bachelor's in engineering the same year that the *Challenger* blew up. She is young enough to think of Sputnik as ancient history and to consider a career in space exploration as nothing unusual.

"If we're slow getting the engines out, then we won't have as much time to work on them, which means it will be slow getting them back in," says Webb. "This can snowball." Pulling the engines for servicing is just the beginning. To prepare for its mission to launch the Hubble telescope, *Discovery* underwent some 36 modifications during its previous stay in the Orbiter Processing Facility last winter. New carbon brakes were installed to provide greater stopping power and control during landing. The

The Vehicle Assembly Building has more than 70 lifting devices, including two 250-ton bridge cranes.

high-pressure oxidizer turbopumps on the main engines were equipped for the first time with sensors to provide data on bearing wear.

Now two months later *Discovery* hangs motionless above the floor once again. Technicians routinely check for damaged items. Their tools range from a simple lug wrench to a "smart" torque wrench, which gives a digital display of the force being exerted and an audible click when the correct torque has been applied. It's just one of more than 1,700 special shop aids available.

Often tools have to be hand-crafted to repair the 24,000 tiles that cover each shuttle's underside, wings, and other areas exposed to high temperatures during reentry. Early shuttle missions were plagued by tiles that kept falling off, but new materials and advanced bonding techniques have ensured that tiles are seldom lost anymore. Still, they have been damaged by ice shaken loose from the external tank at liftoff, stones kicked up from the runway at landing, and even rain encountered during the ferrying flight back to Kennedy.

Replacing tiles is a very precise operation. Measuring and calculating the placement of each one takes about two hours. "In the construction business, if you mess something up you can go back the next day and fix it," says Greg Grantham, who built aluminum store fronts for a living before he became a shuttle tile technician. "Here they might launch it the next day."

In addition to the repair work on the orbiter's structure, its payload bay must be cleaned and reconfigured for the next flight. Payload bays sometimes return full, as was the case last January when *Columbia* brought back the Long-Duration Exposure Facility, a schoolbus-size satellite rescued from a decaying orbit (see "What Goes Up . . . ," August/September 1989). Because the bay's hinges aren't designed for use in normal gravity, special counterweights must be used to simulate the zero-G condition of space.

Technicians wearing plastic gloves and hoods covering their hair prepare the bay for new payloads. Some are loaded while the shuttle is horizontal. Those that can be installed in the vertical position will be added when the orbiter is on the launch pad.

Riding herd in the Orbital Processing Facility are the flow directors, the managers who pull the various jobs together. Each of the three shuttles has its own flow director. Their main adversaries are the "pokers," problems that "poke out of the flow, out of schedule, so you've got to work around them and accommodate them," says Tip Talone, flow director for the *Discovery* shuttle. "If we run into a problem," he explains, "we will just replan it and push the launch date back."

Work continues around the clock, three shifts a day, seven days a week, by thousands of contract employees. If they lived in Detroit, many would probably be building cars. Because they live near Cape Canaveral they work for private companies that perform much of the work for NASA. The prime contractor for launch preparation is Lockheed Space Operations, which works with teams from EG&G, Morton Thiokol, McDonnell Douglas, Rocketdyne, and United Technologies.

NASA operations engineers like Jennifer Webb grade the performance of the contractors. While she encourages and advises, she doesn't command them. That's left to her contractor counterpart. "Sometimes it will be very calm; it just works like a clock," says Webb. "Sometimes all hell lets loose. This part's wrong and that guy doesn't have the right piece. There's not enough people to do an operation and an engineer left for the day and his papers are all hunked up."

For two to three months the shuttle lies horizontal in the Orbiter Processing Facility. While it is serviced a metamorphosis has been taking place less than half a mile away in the Vehicle Assembly Building. Another crew has been stacking the two solid rocket boosters on a mobile launcher platform, where they will be mated to the 15-story-tall external tank. When it's ready, the orbiter is towed to the assembly building to take part in this extraordinary transformation.

One of the largest buildings in the world—its floor covers eight acres—the assembly building is the former home of the Apollo Saturn V rockets and the heart of Launch Complex 39. Here more than 70 lifting devices, including two 250-ton bridge cranes, will transform the prone orbiter into a vertical rocket ready for launch.

It's a secretive rite of passage. Guards are posted at the entrances as workers attach cables to the orbiter and set the winches. A crane-like hoist pulls the 87.5-ton orbiter into a vertical position until it dangles like a puppet 200 feet above the floor. Then it is positioned above the mobile launcher platform. As it is inched downward, its wings slide into place beside the external tank and two solid rocket boosters. Struts on the external tank align with a bracket near the orbiter's nose and two other brackets by its wings. These three connecting points are then fas-

Work platforms allow technicians to check connections between the orbiter, boosters, and external tank.

Morton Higgs (left) and S.W. "Buz" Brown monitor fuel operations and watch for leaks at the pad.


USA
NASA

It takes the crawler-transporter six hours to deliver the shuttle from the Vehicle Assembly Building to the launch pad four miles away.

tened with bolts 28 inches long and 3.5 inches in diameter. The delicate process takes about 18 hours.

The orbiter will remain upright until launch. Now it's time to test connections between the orbiter, the external tank, the solid rocket boosters, and the mobile launcher platform. Hundreds of electrical wires run through five pipes and hoses that connect the orbiter and the external tank. This is the first time that an all-up integrated test can be run, and it lasts about five days.

The final activity in the assembly building is the aft installation of ordnance: explosive bolts that the orbiter will require when it's time to break free from the launch pad.

Launch pad 39-A, NASA's workhorse, sits beside the Atlantic Ocean four miles from the Vehicle Assembly Building. To move the shuttle from one to the other, Kennedy personnel use one of the biggest land vehicles in the world: the crawler-transporter.

Designed to lift, hold, and move the largest, tallest, and heaviest known portable structures on earth, the crawlers (NASA has two) were originally used to transport the Saturn V moon rocket. Sixteen hydraulic jacks—four at each corner—lift the 4,000-ton mobile launch platform and 2,250-ton shuttle. The crawler itself weighs 3,000 tons and is powered by two 2,750-horsepower diesel engines.

When it's loaded the crawler has a top speed of 1 mph, and the trip to the pad takes six hours on a roadway—the "crawlerway"—almost as broad as an eight-lane turnpike. Both crawlers now have hundreds of miles on odometers that first started turning in the Apollo years. Once it arrives at the launch pad, the crawler places the launch platform on a set of pedestals that position the shuttle engines and solid rocket motors above a reinforced-concrete flame trench.

Somewhere between two to four weeks before launch, the computer begins pumping fuel—monomethyl hydrazine and its oxidizer, nitrogen tetroxide—into tanks supplying the maneuvering jets on the exterior of the shuttle. In the early days of the program, these fuels were loaded by workers in white rubber SCAPES—self-contained atmosphere protection ensemble suits—who opened and closed valves by hand. "We have gradually changed the hardware and written the software until now most of that is automatic," says S.W. "Buz" Brown, manager of operations at launch pad 39-B.

"We get a lot of small leaks," says technician Morton Higgs. "If it runs on the floor, we have sponges to pick it up and put it into a bucket." Higgs uses the equivalent of a wet/dry vacuum when a thin stream of hydrazine dribbles down the fuel line. The worst leak happened almost a decade ago, when a fuel line connector broke. "We had propellant flowing down the belly of the orbiter," recalls Brown. "We had a lot of tiles to replace."

NASA test director Michael Leinbach monitors the shuttle's pre-launch sequence from the firing room.

Nine hours before launch the computer starts pumping liquid oxygen and liquid hydrogen into the two compartments of the shuttle external tank. The top compartment holds 143,000 gallons of liquid oxygen. The bottom, more than two times larger, holds 385,000 gallons of liquid hydrogen. Fueling takes about three hours.

Last summer hydrogen leaks resulted in the temporary grounding of the entire shuttle fleet. *Atlantis*, which was scheduled to fly a classified defense department mission, suffered from a leak

Approximately five months after it arrived, a shuttle blasts off from Kennedy Space Center to start the sequence all over again.

in a 17-inch-diameter pipe that carries liquid hydrogen from the external tank to the orbiter's main engines. A similar leak plagued *Columbia,* which was preparing to deploy NASA's Astro-1 X-ray and ultraviolet observatory.

Leaks aren't the only problems that occur on the launch pad. Last April one of *Discovery*'s auxiliary power units failed at T minus four minutes. The replacement APU came off the *Atlantis*—at the time in the processing facility being prepared for a July launch. Even though the practice of cannibalizing parts was soundly criticized by the presidential commission that investigated the *Challenger* tragedy, it still occurs and even proved to be the solution to *Columbia*'s hydrogen leak—NASA replaced the leaky hardware with parts from the shuttle *Endeavour,* which is currently under construction.

"You try to avoid it wherever possible, but it does happen," says Jennifer Webb. She recalls another incident when a transponder, or radio beacon, was taken off *Discovery* for the *Atlantis* flight in February 1990, even though *Discovery* was scheduled to fly in less than two months. "If we hadn't been into a countdown situation I don't think they would have done that," she says.

Columbia had a problem with cannibalization after the *Challenger* accident. "We kept taking parts off of it," Webb says. "We took an entire antenna for a *Discovery* flight. It gave up a lot of parts before it flew [in August 1989]."

The decision to cannibalize is made at the level of flow director or higher. The managers, Webb says, have to establish priorities. "Like what they say at the launch pad [when they request parts from a shuttle in the processing facility]: 'They've never launched one from the horizontal yet.' So we say, 'Okay, you can have it.' "

After months of processing, the shuttle is now ready, and the launch support team watches its television monitors for the pre-programmed checks. The flaps and wing elevons, speed brake, rudder, and ailerons all wave to the controllers as the computer puts them through their paces.

In the final minutes prior to launch, computers take over. At T minus 6.6 seconds, the main engines ignite. The shuttle rocks 25.5 inches toward the external tank, then back as the main engines reach 104 percent thrust. As soon as the shuttle is exactly vertical, at T minus 0, the solid rocket motors fire. Explosive bolts holding the shuttle to the pad splinter and drop into sand pits below. Umbilicals release.

Gathering momentum, the shuttle lumbers off the pad. As the spacecraft clears the tower, Houston takes control of the mission. For those at the Kennedy Space Center it's a gratifying instant—and time to get back to the other two shuttles awaiting their turn.

Perhaps the symbol that best captures the spirit of those who fought victoriously in the Battle of Britain 50 years ago is the English fighter plane, the Spitfire.

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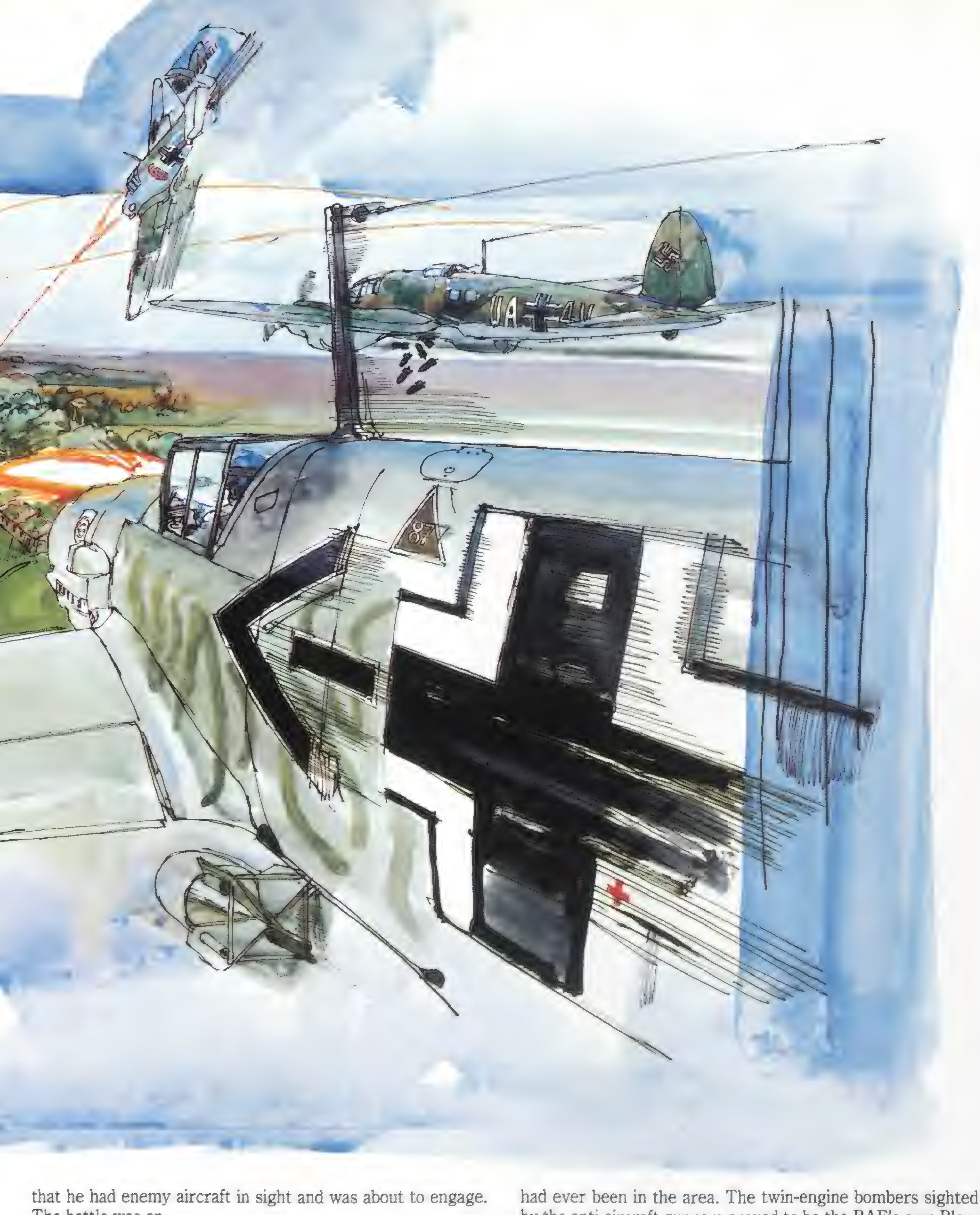
The Eyes of England

The Luftwaffe
had the advantage
in numbers—
but the RAF had radar.

The Battle of Britain:
50 Years Later
Third in a Series

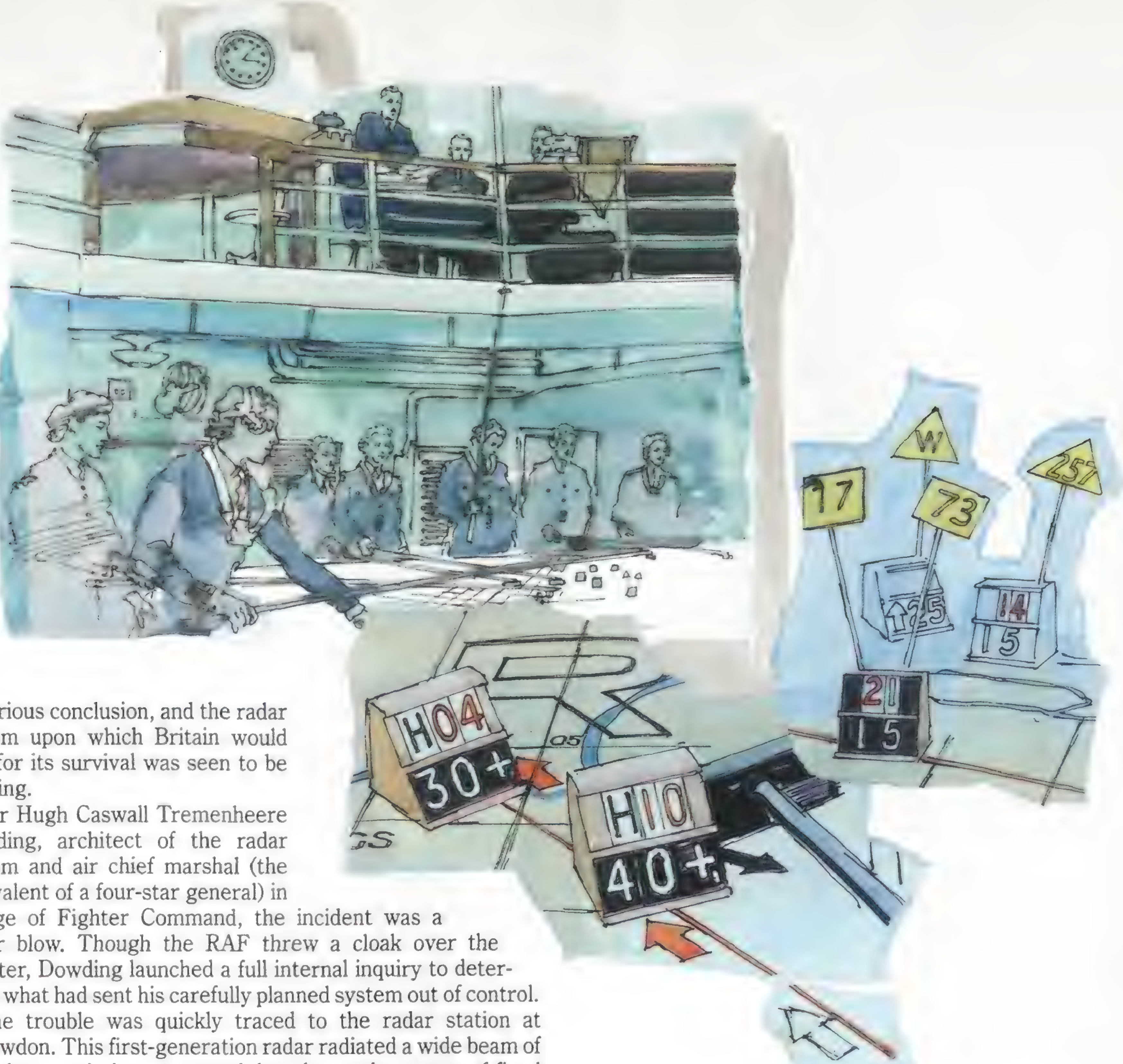
by Alfred Price *Illustrations by Ken Dallison*

On the morning of September 6, 1939, a Chain Home radar station at Canewdon on England's east coast detected a formation of unidentified aircraft, estimated at 20 strong, apparently heading toward London from the east. Britain had declared war on Germany only three days earlier, and it looked like the Luftwaffe had begun the expected aerial onslaught against England's capital. Fighter squadrons were scrambled to intercept the intruders, and within a few minutes the incoming radar blips, now designated as hostile, increased from one formation to 12. Throughout the city, sirens warbled their warning, and people scurried for shelter underground. Before long an anti-aircraft gun battery on the Thames Estuary reported a formation of twin-engine bombers within range and opened fire. Then the leader of a Spitfire squadron radioed



that he had enemy aircraft in sight and was about to engage. The battle was on.

For nearly an hour, chaos reigned over the Thames Estuary. Finally the Spitfires and Hurricanes ran short of fuel and returned to their bases. The Royal Air Force had lost three aircraft and one pilot, but when all the evidence was studied days later, it became clear that not a single German aircraft had ever been in the area. The twin-engine bombers sighted by the anti-aircraft gunners proved to be the RAF's own Blenheim fighters, one of which was shot down. The fighters engaged by the Spitfire squadron turned out to be Hurricanes from another unit, and two of these were shot down as well. What came to be called the Battle of Barking Creek (named for a locale in English dance hall comic routines) had reached its



inglorious conclusion, and the radar system upon which Britain would rely for its survival was seen to be wanting.

For Hugh Caswall Tremenheere Dowding, architect of the radar system and air chief marshal (the equivalent of a four-star general) in charge of Fighter Command, the incident was a bitter blow. Though the RAF threw a cloak over the disaster, Dowding launched a full internal inquiry to determine what had sent his carefully planned system out of control.

The trouble was quickly traced to the radar station at Canewdon. This first-generation radar radiated a wide beam of pulsed transmissions eastward, but the crude system of fixed antennas leaked considerable power westward. Echoes coming from objects to the west, behind the radar, should have been detected as such by the operator, but on that day the radar's sensing system had not been operating properly, and aircraft flying to the west of the radar appeared on the screen as if they were to the east. As additional RAF fighters took off and climbed to engage the "enemy," their echoes appeared to enlarge the phantom raiding force, contributing to a chain reaction in which the raiding force seemed to grow ever larger.

None of the other radar stations overlooking the Thames Estuary had reported incoming aircraft that day, which should have aroused suspicion. If nothing else, the Barking Creek incident showed the dangers of relying too heavily on information from a single station. Despite such shortcomings, radar was to be the keystone of England's defense against air attack, and the RAF would have just enough time to complete its network of electronic eyes before the Battle of Britain broke in the summer of 1940. By the spring of that year, an array of 21 Chain Home (CH) stations provided overlapping radar coverage of the south and east coasts of England and the east coast of Scotland. Positioned between the CH stations was a new type of radar that operated on a shorter wavelength, providing an improved screen at lower altitudes and out to a maximum range of 50 miles. This new Chain Home Low (CHL) network was the final interlocking piece in Dowding's air defense system, a work of genius that had its origins in events that had occurred 23 years earlier.

In July 1917, 20 German Gotha bombers staged a daylight raid on London, leaving 162 dead and 432 wounded. The Gothas flew at only 60 mph at an altitude of about 10,000 feet, yet they were unopposed by British aircraft. The resulting public outcry prompted the British government to improve Britain's fighter and gun defenses throughout the rest of World War I.

By 1918 a reasonably efficient network of ground observer posts was in place throughout southern England. Telephone lines linked these posts to fighter control centers, where reports of enemy planes were collated and plotted on maps. Officers directing the defense could visualize the flow of battle and keep track of the raiders, and although the defending airplanes lacked radios, they could be guided toward the ene-

my by large white arrows laid out on the ground at prearranged points. The system was rudimentary but adequate against biplanes that took an hour or more to cover the distance from the coast to London.

During World War I, Dowding served with the Royal Flying Corps in France, commanding Number 16 Squadron in 1915 as a 33-year-old major and experiencing his first air combat. That summer, the Germans introduced a Fokker monoplane with a fixed machine gun synchronized to fire between the propeller blades. This new airplane rapidly established air superiority over the slower British and French types, and flying in combat against an enemy equipped with technically superior aircraft made a profound impression on Dowding.

In 1930 Dowding was promoted to air vice marshal (equivalent to a two-star general) and assigned a seat on the Air Council, the governing body of the Royal Air Force. The early 1930s saw rapid advances in aviation, and Dowding's department was responsible for developing and producing new aircraft and equipment for the service. In January 1933 Adolf Hitler became chancellor of Germany; by March he had assumed total control. The situation in Europe deteriorated rapidly, and the Luftwaffe became a modern fighting force that threatened England. Dowding's department drew up specifications for high-performance monoplane interceptors to match the Luftwaffe's new generation of high-speed bombers and fighters, and from such initiatives came prototypes of the Spitfire and Hurricane.

Dowding saw clearly that even his new fighters were unlikely to prevent 160-mph bombers flying at 20,000 feet from reaching their targets. The best British fighters would take about 20 minutes from the time they were scrambled to reach a height from which they could move into position to intercept an enemy force at such a high altitude—about the same amount of time it took a formation of the new Luftwaffe bombers to reach London from the coast of England (see "Turning Up the Boost," p. 88). To intercept an attacking force effectively, the fighters had to be airborne before the raiders came within sight of ground observers. This meant that in time of war, some fighters would have to be kept on airborne patrol in order to meet bombers sighted from the coast. But that was very inefficient and wore out pilots and airplanes. Dowding saw that more help was needed from the ground.

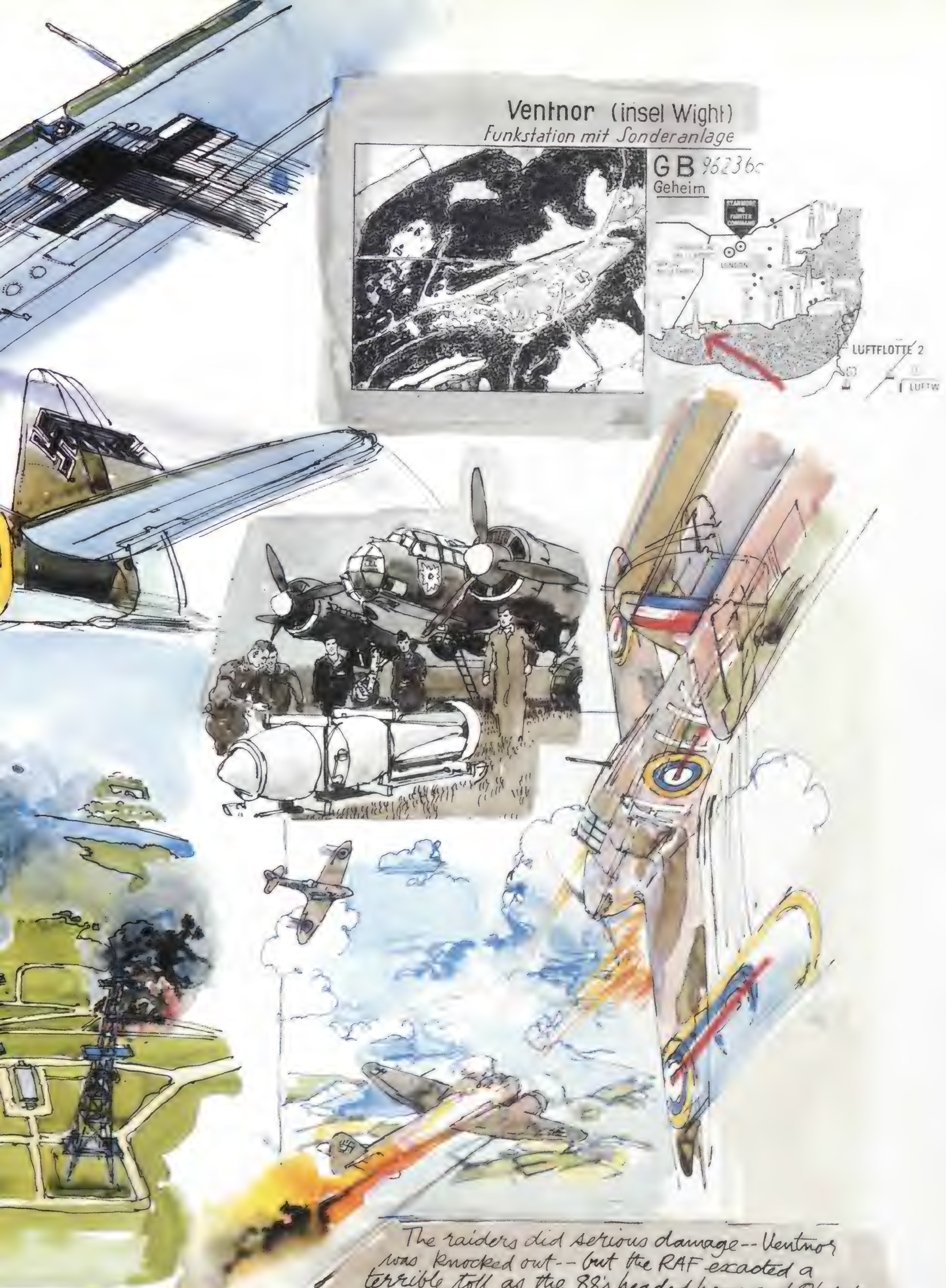
The ground component of Britain's air defense system had changed little since World War I. The Observer Corps was still in place, and the telephone network enabled information to be passed quickly. Work had started on a long-range eye—or, more accurately, ear—to gain an earlier warning by detecting and amplifying the noise from aircraft engines, with a range of 25 miles as the goal. Even under the best conditions, the largest of these acoustic detectors, which employed a curved and carefully smoothed wall of concrete 200 feet long and 25 feet high to collect distant sounds, could not detect aircraft more than 15 miles away. Something much better was needed.

By the early 1930s rapidly evolving radio technology had produced the four building blocks needed for a radio-echo detection system, the device we now call radar: a transmitter to generate powerful pulsed signals, a directional antenna to focus those signals in the right direction, a receiver sensitive enough to detect and amplify the feeble echoes returning from the target, and a cathode ray tube to display the amplified echoes visually.

Here was the long-range eye Britain needed for effective fighter control, and Dowding's department allocated enough funds to develop the new technology. That decision has been ascribed to prescience, but naked fear played a part as well. By late 1936 experimental pulsed radars were working in the United States, Great Britain, Germany, and the Soviet Union. Of those nations, none was more vulnerable to air attack than Britain. London lay within 90 miles of foreign territory and within 275 miles of Germany.

By mid-1935, the first British pulsed radar, set up by Robert Watson-Watt's team at Orfordness, was tracking aircraft to a maximum range of 38 miles. This radar was very much a first generation, without the rotating beam one associates


The last significant Luftwaffe raid directed against British radar was staged on August 12 by KG 51, which attacked the CH station at Ventnor on the Isle of Wight with its Ju 88's...



The raiders did serious damage--Ventnor was knocked out--but the RAF exacted a terrible toll as the 88's headed home and Oberst Fisser, the unit commander, was killed. Göring ordered an end to attacks on radar.

Turning Up the Boost

In June 1939 the tanker *Beaconhill* sailed from Aruba to England with a cargo as precious as gold: an improved aviation gasoline that would add power to the Royal Air Force's Hurricanes and Spitfires. Along with radar, the gasoline would tip the technological balance in favor of the British.

The gasoline was a blend of iso-octane (produced by the alkylation process) and a gasoline refined from a Venezuelan crude oil with high aromatic content and the addition of tetraethyl lead. Gasoline contains families of hydrocarbons having markedly different shapes: straight-chain paraffinic gasoline has little resistance to detonation, a form of engine knock, but branched-chain and aromatic molecules (based on a hexagonal ring of six carbon atoms) have excellent knock resistance.

The Rolls-Royce Merlin engine delivered about 1,000 horsepower running on 87 octane gasoline. Its power output was limited by the compression, or boost, of its supercharger, but more directly by the fuel's tendency to detonate when too much boost was applied. In a letter to the Rolls-Royce Heritage Trust, Alexander R. Ogston, one of the principals in the effort to obtain the new fuel for the RAF, described its key role:

"[Rolls engineer] Stanley Hooker's improvement of the Merlin supercharger's efficiency in 1938/39 was the first step that brought about the need for 100 octane (instead of 87) which permitted the use of 12 lb boost (instead of 6 lb) for take off and climb. In the 1940 air battle, as soon as German Luftwaffe aircraft were detected by the RAF radar stations, Fighter Command Spitfires and Hurricanes were immediately 'scrambled' and every pilot's objective was to be able to engage the enemy with an advantage in altitude . . . . Prior to the Battle of Britain, Air Chief Marshal Dowding and Fighter Command felt that it might be necessary to have standing patrols of Hurricanes and Spitfires at 15,000 to 20,000 feet during the daylight hours so as to ensure that the RAF fighters could engage the enemy with an advantage in altitude and also before the Luftwaffe aircraft crossed the coast. However, the idea of standing patrols was ruled out on the grounds of there being an insufficient number of aircraft and pilots available to support such an operation, not to mention the great increase in flight hours and maintenance . . . . So the only alternative was for the fighter pilots to be at readiness and to scramble to their combat ready aircraft, take off and climb at 12 lb boost to meet the enemy."

According to Ogston, in 1938 the Air Ministry ordered some standard U.S. Army Air Corps fuel rated at 100 octane, but tests showed it lacked "rich mixture response"—enhanced resistance to detonation when the fuel-air mixture was enriched. However, it turned out that the fuel systems on the U.S. aircraft were sealed with rubber materials that dissolved in aromatic gasoline, so the Army had specified a more paraffinic blend. When the British switched to high-aromatic fuel, the boost could be increased to 12 pounds and the Merlins gained 300 hp. Dowding's radar net found the Luftwaffe aircraft, and the 100-octane gasoline ensured that the RAF fighters would intercept them in time.

—*George C. Larson*

with modern surveillance radar. Instead, the transmitter sent out a beam covering a zone of about 60 degrees in front of the station, and radar operators used direction-finding methods to measure the altitude and elevation of any echoes.

By March 1936 the range of the radar had risen to 62 miles, and at the end of that year the device was working reliably enough for the British government to order 20 early-warning radars—designated Chain Home—to form a network of stations along the east coast. (The code name "Chain Home" arose from a plan to build a "home chain" of radars in Britain, to be followed by an overseas chain to defend threatened portions of the Empire.) Despite the primitive concept of the CH radar and the fact that once it was running several major technical improvements suggested themselves, the decision was made to leave well enough alone, and the equipment went into production with only minor improvements on the original design. A satisfactory early-warning system had to be placed in service as rapidly as possible so that service personnel could learn to operate it. In fact, CH radar would remain the primary British long-range early-warning radar until well into World War II.

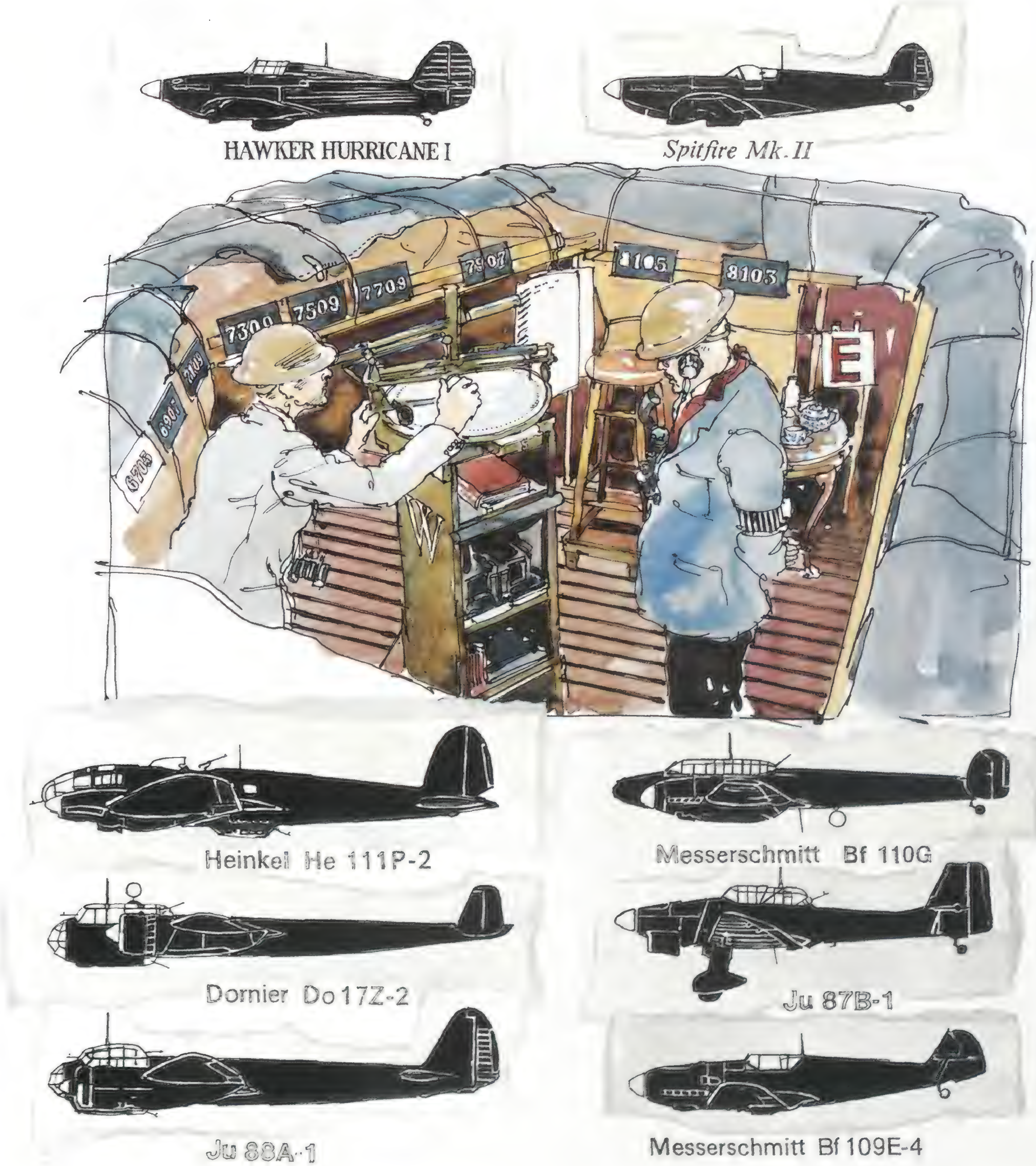
In 1933 Dowding was promoted to air marshal (three-star equivalent) and knighted. In July 1936 he was appointed commander in chief of Fighter Command, and soon afterward he was promoted to air chief marshal. To his pilots, Dowding seemed a complex and aloof character with none of the extrovert's qualities one might expect from a fighter leader. Behind his back he was called "Stuffy." He was like a character in a play who exerts a continual influence on events but seldom appears on stage.

By April 1937 the first operational radar station, situated at Bawdsey in Suffolk, took part in a small-scale exercise in which aircraft were observed at ranges up to 80 miles. In August 1938 Fighter Command staged a major exercise in which five stations were operational.

By now Dowding was as aware of radar's limitations as he was of its possibilities. It was most effective when looking out to sea; echoes from terrain made plotting aircraft over land almost impossible unless the radar was sited in an area of exceptionally, flat ground. Its height-finding was unreliable when its targets were flying below 7,000 feet or above 25,000 feet. Each CH radar set required a team of seven to determine the positions and altitudes of each blip, and because its indications were imprecise and liable to cause confusion, its operators could not guide fighters directly to hostile targets the way interceptions are run today.

CH radar replaced the sound locator as a source of early warnings, but the new device was integrated into a fighter control organization remarkably similar to that used during World War I. Observers at ground posts still tracked enemy aircraft visually, and both they and the radar stations passed their information to the same control centers, which presented it all on maps. There were differences as well: by now all British fighters were equipped with radios, which made for more effective control than arrows laid out on the ground.

The control centers could track enemy and friendly aircraft, but, as had been evident even before the Barking Creek incident, it was vitally important to have some means of distinguishing friendly aircraft from hostile ones on radar. Such a



device, called IFF for Identification Friend or Foe, was already entering production at the time of that debacle, and in the months that followed, every RAF combat aircraft was fitted with it. When triggered by a radar pulse from a ground station, the IFF replied with a coded signal that produced a distinctive shape to the blip on the radar screen.

In order to distinguish one friendly unit from another, a radio modification named "Pipsqueak" was developed: once a minute, a device automatically switched the radio of one fighter in each formation to transmit for 14 seconds. Three direction-finding receivers in each fighter sector took bearings on the transmissions and resolved the formation's position by triangulation at the sector operations room. This information too was passed to the group operations room.

Although the guiding hand in this grand design was Dowding's, the system for controlling fighters evolved from hard and sometimes inspired work by several small teams over a long period. It was the product of common sense and a clever meld of proven old methods and new—though not the newest—technology. Most squadron pilots did not even know of the existence of radar. During the numerous exercises to test each element of the system and develop operating procedures, the pilots received their intercept vectors in the same language as they had before radar came into use. They never knew the source of the information on which they were acting—nor did they need to know.

When the Battle of Britain opened in July 1940, Dowding's fighter control system was ready for its big test. "We had done literally thousands of practice interceptions during the 'phony war,' " recalls Squadron Leader Anthony Norman, a former fighter controller for the Kenley Sector. "We were absolutely confident that nothing could come over the coast unseen by some element of the system." That confidence was not misplaced—the system worked.

As soon as personnel at the coastal radar stations detected incoming aircraft, they telephoned the plots to the Filter Room at Fighter Command's headquarters at Stanmore Park, north of London. There the radar plots were compared with known positions of RAF aircraft. If no friendlies were in the area and no IFF signals were present, the plot was designated as "unidentified" or "hostile" and passed to fighter group and sector operations rooms.

Group operations rooms were large underground installations. The smaller sector operations rooms were located at the main fighter base for each sector. The group controller decided when to scramble squadrons and from which sectors they should come. Once the fighters were airborne, the sector control room directed its own squadrons into action and brought them back to base afterwards.

Fighter Command had four fighter groups numbered 10 through 13, each divided into a varying number of sectors whose boundaries were marked on operational maps. Number 11 Group defended London and southeastern England, and its operations room, from which much of the Battle of Britain was directed, was situated a hundred feet below ground at Uxbridge, west of London. It resembled a small theater in which a large table with a gridded map of southern England and the north coast of France occupied the center of the stage. About a dozen men and women fussed around the table keeping the plots up to date. The plotters, mostly women, used rakes similar to those used by croupiers in gambling casinos to move small wooden blocks representing aircraft or forces of aircraft. Blocks representing friendly fighter units were topped with metal tabs showing squadron numbers, while blocks representing hostile or unidentified aircraft carried no such tabs but bore the letter "H" or "X" with numbers to facilitate tracking. Lower down the blocks, other tags indicated the number of aircraft present and their altitude.

When a raiding force began moving in, the noise level in the operations room grew along with the excitement. "The whole thing could best be described as organized chaos," recalls Vera Saies, a former plotter in the operations room at Uxbridge. "When things got going, plots from the Filter Room were coming at about five per minute on each track. Girls would be calling for new counters to update their blocks, runners would be dashing to get them from the table beside the plotting map. If one asked for one thing and one's neighbor asked for something else, it was a matter of who shouted loudest. It was all so unlike the quiet, relaxed atmosphere often depicted in films."

Looking down from the upper circle behind a soundproof glass partition sat the group fighter controllers. "They seemed so calm, far removed from the hubbub below," Saies recalls. "If things there had been as chaotic as they were with us, I don't think we could have won the battle." As raiders neared the coast the controllers ordered their squadrons to scramble, climb to altitude, and patrol along designated lines. The process was like positioning football players for a kickoff. "Each minute of unnecessary delay waiting to make absolutely sure that the raid was coming in meant about 2,000 feet of vital altitude our fighters would not have when they met the enemy," recalls Wing Commander Lord Willoughby de Broke, who was senior fighter controller at Uxbridge throughout the Battle of Britain. When the raiding force crossed the coast and came within view of the ground observer posts, the aircraft were counted and the types identified. This information was also passed to the Filter Room and the various operations rooms.

Once airborne, the individual fighter squadrons were directed into action by radio from their sector operations rooms. The rooms were small-scale replicas of the one at Uxbridge, except that almost all were exposed above ground (a vulnerability the Luftwaffe apparently never realized) and inside, half a dozen plotters updated the situation map. From here, the sector controller passed intercept vectors to the fighters. "My job was not only to put the fighter squadrons in position to intercept but also put them into a position where they could intercept with advantage," Norman explains. "So we would not aim them straight at enemy formations. Instead we would try to place them a little to the south so that they could attack from out of the sun and, if possible, with the advantage of

height." Altitude was the fighter pilot's treasure, to be traded for speed when the situation demanded.

Typically, the first British squadrons would be ordered into the air within a couple of minutes of the initial report of a Luftwaffe force assembling over northern France. They might go into action about 30 minutes later and be back on the ground 10 minutes after that, having exhausted all of their ammunition.

In an air action the margin between success and failure is often fine, and during the Battle there were several occasions when defending fighters failed to close with the enemy. But in general the fighter control organization stood up well to its baptism of fire. The system's severest test as well as what may have been Dowding's greatest hour of triumph came during a climactic clash on September 15, still celebrated each year in Britain as "Battle of Britain Day."

That Sunday, the Luftwaffe planned to deliver its heaviest blow yet against London. In two attacks separated by a couple of hours, its bombers were to hit rail targets in the capital first, then go on to attack three of the most important dock areas. Every Bf.109 in Luftflotte 2 was to take part in escorting the force. Several units would even have to fly two sorties.

Almost from the start the Luftwaffe plan went awry. As they climbed to attack altitude over France, the Dornier bombers ran into a layer of dense cloud that forced them to break formation. It took them 10 minutes to rejoin above the cloud; then they continued on to the Pas de Calais to rendezvous with their fighter escort. The force turned onto a northwesterly heading for London but encountered more delay from a 90-mph headwind. The large formation had been seen by British radar when it was climbing over France, and each additional minute gave Dowding's controllers more time to organize the defense.

The Bf.109 fighter-bombers reached the capital first and attacked from above 20,000 feet, scattering their bombs across a wide area and withdrawing without a loss. They did little damage and left few casualties. Coming up behind at 16,000 feet the Dorniers and their escorts were harried across Kent by 11 squadrons of Spitfires and Hurricanes. The Messerschmitts protected their charges well, and the raiding force reached the outskirts of London without losing a single bomber. But the force had arrived at the capital more than half

an hour later than planned, and by the time the 109s reached the southern outskirts of London they were so low on fuel they had to turn for home. The Dorniers flew on without an escort.

Number 11 Group commander Keith Park planned to fight his main action over the capital, where 12 fresh squadrons of fighters were poised. As the fighters ran in to attack the raiders, one Dornier's crew loosed a new secret weapon: a flamethrower installed in the airplane's tail. But the oily fuel wouldn't burn well at high altitude, and the flame and smoke only drew more fighters, which quickly shot the bomber down. During the action nine more Dorniers were knocked out of formation. Five were quickly finished off by fighters, and four escaped into cloud. The rest, many of them damaged, held tight formation and continued to fight off their attackers. (Three-quarters of them would get home, a testament to the leadership of Major Alois Lindmayr and the discipline and skill of his crews. By any yardstick it was a brilliant fighting withdrawal.) Finally the departing bombers linked up with 109s assigned to cover the withdrawal, and the 90-mph wind helped them homeward.

Before the survivors landed, a far larger raiding force was forming to attack the three dock areas east of London, and soon the plotting tables at Uxbridge were alive with new tracks. The huge enemy force phoned in by the radar plotters would turn out to be 114 bombers flying in three parallel columns about three miles apart, with large numbers of escorts. Soon after the formations crossed the coast three squadrons of Spitfires went into action, tangling immediately with the 109s. By now it was clear that a major attack on London was in the offing. Park ordered all 21 of his Spitfire and

Hurricane squadrons into the air. Number 12 Group sent Douglas Bader with five squadrons forming his vaunted "Big Wing." And from the west, Number 10 Group sent three squadrons to the capital. Fighter Command's forces in the southeast of England were now at full stretch.

Prime Minister Winston Churchill happened to be visiting Park's operations room at Uxbridge that day, and he was present as the action unfolded on the main plotting table. In his memoirs, he later wrote: "I became conscious of the anxiety of the Commander, who now stood still behind his subordinate's chair. Hitherto I had watched in silence. I now asked: 'What other reserves have we?' 'There are none,' said Air Vice Marshal Park. In an account which he wrote about it afterwards he said that at this I 'looked grave.' Well I might. What losses should we not suffer if our refuelling planes were caught on the ground by further raids of '40 plus' or '50 plus'! The odds were great; our margins small; the stakes infinite."

As he had earlier, Park concentrated the bulk of his force on the blocking of London. No fewer than 185 fighters from 19 squadrons were in position. Again the Luftwaffe formations coming across Kent were harried, and for Messerschmitt pilots assigned to close escort of the bombers this was a particularly frustrating time. They were not permitted to pursue RAF fighters to the kill if doing so meant leaving their charges. Repeatedly they had to break off the chase and rejoin their formations, only to have the British return to the battle.

As the raiding force came within range of the anti-aircraft batteries deployed along the Thames, a concentration of 4.5- and 3.7-inch guns at Chatham loosed a barrage that damaged several bombers. Now Bader's five squadrons arrived over London and came under attack from free-hunting 109s diving from above. Bader ordered his three Hurricane squadrons to split up and engage the fighters while, in a reversal of their usual role, the Spitfires went for the bombers. All five bomber groups reached London essentially intact and now lined up for bomb runs on the docks.

During the late morning and early afternoon, clouds had been building over southern England. Now there was almost continuous cover, extending from 2,000 to 12,000 feet, obliterating the Luftwaffe targets. Two groups dropped on the district of West Ham, causing heavy damage, while others turned for home and scattered their bombs without serious effect.

At 3:25 p.m.—about an hour after Churchill and Park had been in grim conversation—the tote board at Uxbridge revealed that a Hurricane squadron at Tangmere was now refueled, rearmed, and ready for action. Park had a slender fighting reserve. Within minutes, other squadrons called in reporting "at readiness." The crisis was over.

The extensive cloud over southern England that afternoon made it difficult for ground observers to plot enemy movements. In spite of this, the action saw Dowding's system of fighter control performing at its triumphant best: 28 squadrons of Spitfires and Hurricanes had been scrambled, and every one of them found the enemy and went into action. One hundred percent is difficult to improve upon.

That evening the defenders jubilantly announced the destruction of 185 Luftwaffe aircraft. The real figures were 56 shot down and 23 damaged, but that was sufficient. Hugh Dowding, who had built Britain's front line of defense over a period of 10 years, witnessed the vindication of his efforts as that line held.

UPI/BETTMANN

An expedition to the Amazon was one of the many projects Sherman Fairchild (top, at right) pursued as he pioneered the industry of aerial surveying. Fairchild's mapping cameras greatly improved military reconnaissance (right).

Sherman Fairchild Looks at the World

How a millionaire inventor got the bugs out of shutters and made accurate aerial photography possible.

by Anthony Brandt

Sherman Fairchild never met a problem he didn't like—and try to solve. A millionaire industrialist, Fairchild was also a prolific inventor and tinkerer whose interest in all things mechanical dated to his childhood. His creations ranged from the mundane (a non-capsizing bobsled, a match that wouldn't blow out) to the very important—his invention of the first accurate aerial mapping camera for the military enabled photographers to obtain views of the world below that were truly representational.

Born in 1896 in Oneonta, New York, Fairchild was a child of wealth and privilege. His father, George Winthrop Fairchild, was a Republican congressman and one of the founders of International Business Machines, known today as IBM. Young Sherman enrolled at Harvard in 1915, then moved to the University of Arizona, where doctors sent him because of his bouts of tuberculosis. At both institutions Fairchild was constantly tinkering with mechanical devices. At Harvard he rigged up an elaborate pulley system in his dormitory so he could open and shut doors, windows, and blinds from his bed.

When the United States entered World War I in 1917, the 21-year-old Fairchild tried to join the military, but he was rejected because of his health. Nonetheless determined to aid his country's war efforts, he and his influential father went to Washington in 1918 to see if the Army could benefit from the younger Fairchild's photographic expertise. Impressed with the soundness of his ideas, the Army sent Sherman to meet with a Captain Betts of the Army's science and research division in Rochester, New York.

As the boyish, soft-spoken Fairchild described his camera work, Betts' interest grew. On his desk sat one of the European-made aerial cameras that military pilots were using to

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photograph enemy territory. The cameras had one major drawback, Betts told Sherman: their shutters.

The aerial cameras of the day were equipped with focal plane shutters. This type of shutter is a curtain with a slit that travels across the front of the film, progressively exposing it. To obtain different exposures, the size of the slit and the speed of the curtain are varied.

But a focal plane shutter is not ideal for aerial photography: because the airplane is moving at the same time that the slit is traveling across the film, the object photographed below is in one position at the beginning of the exposure and somewhere else by the end of it, yielding a seriously distorted image. In many early aerial photographs, one end appears stretched out in relation to the other. If the distortion had been constant, it could have been corrected, but it varied with the aircraft's altitude and speed as well as the duration of the exposure. Reconnaissance interpreters could use the pictures to identify the nature and approximate positions of enemy emplacements, but because the photographs could not record distances and proportions accurately, they could not be used to make representational aerial maps.

What the Army wanted, Captain Betts told Fairchild, was a highly efficient shutter that exposed the entire film frame simultaneously and eliminated the distortion that came with progressive exposure. A between-the-lens shutter would do the trick. This kind of shutter, constructed of overlapping metal leaves that snap open to expose the film, is sandwiched inside the lens itself. Such shutters were nothing new; they were used on most of the small, hand-held box cameras of the day. But no one had ever designed one large and fast enough to work on an aerial camera. The lenses of box cameras had openings of less than an inch; aerial camera lens openings measured three inches or more. The stresses of opening shutter leaves that wide, holding them open, then snapping them shut, all in 1/100 of a second, would tear the shutter apart. Nonetheless Fairchild promised Betts that he would design a shutter of the requisite size, speed, and efficiency.

Within two weeks, Fairchild had sketched out a new between-the-lens shutter. The elder Fairchild let his enterprising son use the facilities and personnel of his office machinery plant in Endicott, New York, and by March 1919 Fairchild had constructed a workable shutter. He would spend the next few years refining it.

Since no one had ever tried to build such a shutter, Fairchild had no previous designs to work from. He began with a shutter consisting of four thin metal leaves, each attached to a small gear. A large circular gear connected to all of the small gears drove the shutter, but stresses sheared the gear teeth, so he decided to abandon the troublesome gears. His final design consisted of five leaves connected at the base by steel links, so the shutter drive only had to apply power at one point instead of powering all five leaves separately.

After tackling the drive problem, he encountered difficulty with the leaves, which tended to jam and curl. But he managed to solve these problems as well: by overlapping the five leaves he prevented them from jamming, and constructing the leaves out of steel made them light enough to open and close quickly but strong enough not to bend or break under stress. (One minor drawback, which Fairchild soon overcame, was that the shutter seldom lasted through more than 500 exposures without breaking apart from stress on the steel links connecting the leaves.)

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A descendant of the K-3, Fairchild's K-22 proved quite an armful when equipped with a telephoto lens.

By the time the Army accepted his new camera, however, World War I had ended, leaving Fairchild with a product but no buyer. He tried to get the Army to buy his cameras for training purposes, and in the meantime he started taking classes at Columbia University in New York City and rented an office on 42nd Street where he could continue his photography experiments. Finally the Army ordered two cameras. Though a small order, it was enough to sustain Fairchild's enthusiasm.

With his father's help, Fairchild started his first company, Fairchild Aerial Camera Corporation, in February 1920. The startup marked the beginning of Fairchild's illustrious career as an industrialist, but it also marked the end of the kind of life his mother wanted him to lead. Josephine Mills Fairchild felt her son should put aside his mechanical inventions, get a degree at Harvard, follow his father into a distinguished career at IBM, marry the right woman, and live the high society life. Although Fairchild ended up a wealthy man, he would have been even richer if he had held on to his IBM stock instead of selling most of it to finance his many companies. When asked how he got into the aviation industry, Fairchild told *Scientific American* readers in 1930: "It probably was largely a matter of natural perversity. My relations and friends thought I was just wasting my time on what they considered merely a hobby, so I just had to show them they were wrong."

By the end of the year Fairchild had quit Columbia in order to devote all of his time to his business and the improvement of his camera. Although workable, the camera, constructed of bronze, was heavy and unwieldy. Fairchild decided to start over with a new design, and in 1921 he moved his company into a loft above a Chinese restaurant on West 52nd Street.

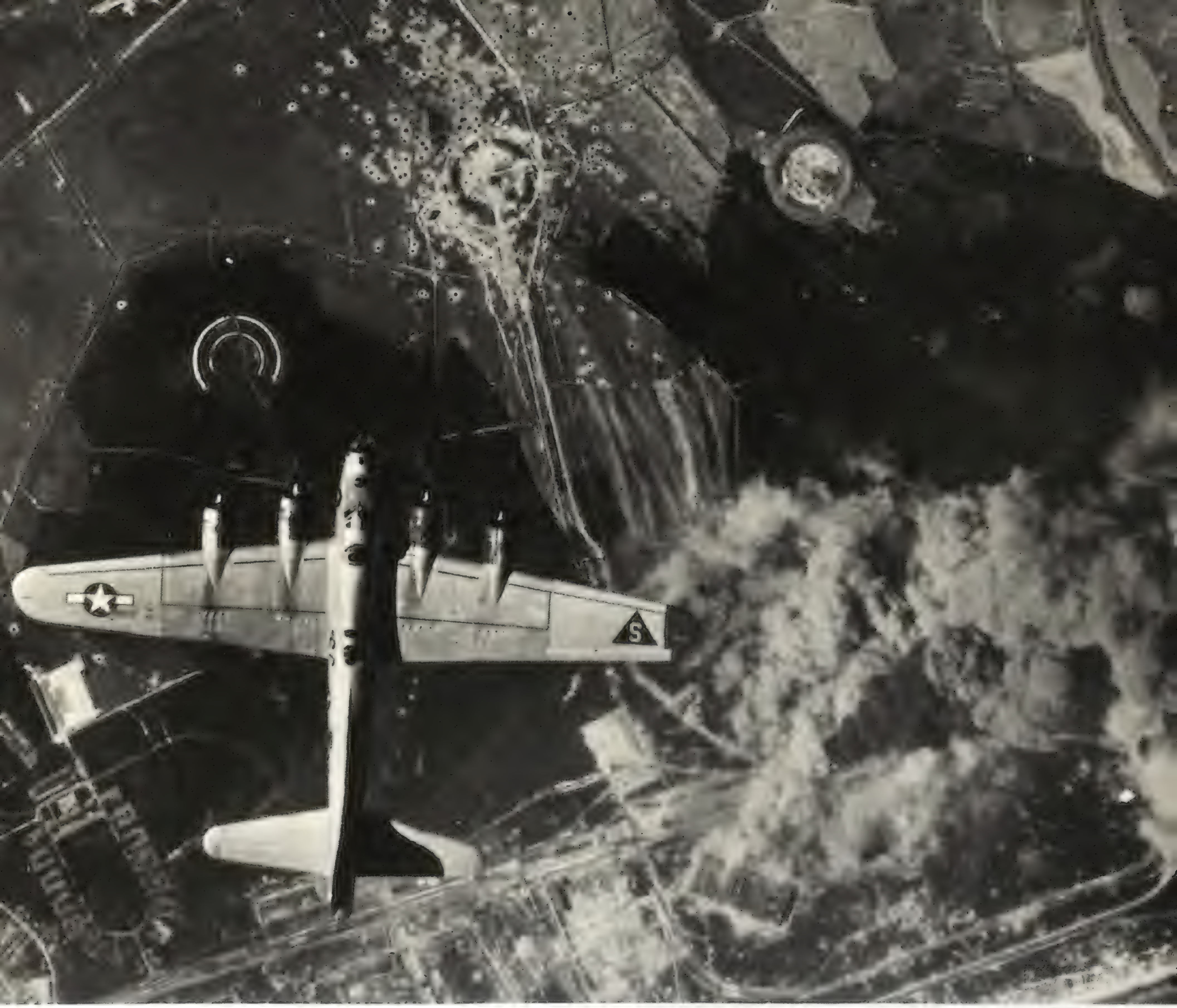
The redesigned camera had a between-the-lens shutter made of five flat steel leaves that were opened and closed by a powerful spring. The shutter operated at speeds of 1/50, 1/100, and 1/150 of a second and let in 85 percent of available light. The camera weighed a total of 46 pounds and carried a 75-foot roll of film that was good for 115 exposures. The Army designated the camera the K-3 and ordered 20 of them; it was not long before the Army made the K-3 its standard aerial camera. The Canadian government eventually followed suit, and the company also did considerable business with Japan, Argentina, Brazil, and the Soviet Union. Subsequent Fairchild cameras, which were variations on the basic design, dominated U.S. military use through World War II.

Although Fairchild had broken into the military market, he had yet to convince surveying companies of the value of aerial mapping cameras. Ever the entrepreneur, Fairchild set about renting an airplane and hiring pilots to go up and take pictures with his cameras. Of his efforts to demonstrate the value of aerial mapping Fairchild said, "The hardest thing in connection with this was educating the public. Nobody had ever used aerial photographic maps and it was an uphill job to put them over." Eventually, though, the idea caught on, and one of the company's first big jobs was mapping Newark, New Jersey, for a fee of $7,000. Other contracts started coming in, and one satisfied customer, the Russell Sage Foundation, wrote: "Aerial photography has now enabled the city planner to see a city exactly as it is. Before the advent of this aid . . . the only way to obtain an idea of the topography of a place was by survey. But now with the city and its suburbs laid out before him in a photograph, he can see at a glance the actual division of the land into blocks, streets, and open spaces. The planner can discover trends in housing and industry and develop an idea of improvement, even before he actually visits the ground."

In 1924 the company completed a map of New York City's five boroughs that was detailed enough to show cars on Fifth Avenue and crowds at Coney Island. That same year the sideline of aerial surveying had grown sufficiently to merit the creation of a new company: Fairchild Aerial Surveys, Incorporated. Fairchild's cameras eventually mapped the entire United States and South America, as well as thousands of square miles all over the world.

Fairchild's restless mind next turned to aircraft design. His pilots and photographers often complained about the harsh conditions of long mapping flights in open-cockpit airplanes: oxygen deprivation, severe cold, and noise and fumes from the engines all had to be endured. So in 1925 Fairchild founded a company just to build airplanes. The company's FC-2 was the first commercially successful high-wing monoplane featuring folding wings, flaps for slow landings, and an enclosed cabin. Aerial photographers loved the warmth and quiet of the cabin, but so did private owners, explorers, airmail pilots, and especially airlines. The airplane's folding wings made the craft easy to store, and their high placement increased visibility from the roomy cabin. The company eventually sold over 40,000 aircraft of all types to civilian and military users worldwide.

Fairchild's companies continued to grow, and more were created: Fairchild Recording Equipment Corporation and Fairchild Semiconductor Corporation. (Over the years Fairchild's



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Aerial photography helped the Allies assess bombing missions, like this B-17 attack on Peenemünde, Germany.

corporate dynasty would undergo many splinterings, buyouts, and reorganizations. In 1989 Fairchild Industries merged with Banner Aeronautical, selling off its space and defense divisions to France's Matra Group.) At one point chairman of all his companies, Fairchild had less time for individual inventions, but he continued to bombard his executives with ideas. The president of Fairchild Camera, John Carter, told a *Time* reporter in 1960 that Fairchild "used to make all sorts of suggestions, but no one ever had the nerve to tell him when they wouldn't work out. Now he still makes all sorts of suggestions. The stuff that's no good we screen the hell out. The stuff that's good we do something about."

After an operation for cancer in the 1950s, Fairchild started working out of his Manhattan townhouse instead of the office. Hardly slowed down, he subscribed to 200 technical journals and kept tape recorders stationed around his house for dictating letters. He kept busy by taking cooking lessons at the Cordon Bleu, practicing jazz piano, and throwing parties. His social life was overseen by his Aunt May, a spinster who had lived with him since his college days.

Fairchild never did marry. He was constantly seen in the company of beautiful women, but none of them could compete with his career. At age 64 he told *Time* magazine, "I don't know why I haven't gotten married. Perhaps it's that I've been so busy. Let's hope it isn't too late. I'm not a bachelor by conviction. I think I am very unfortunate."

In 1970 his cancer returned. A second operation was successful, but Fairchild contracted an infection that antibiotics failed to clear up and exploratory surgery failed to locate.

It would eventually be discovered that the entire batch of intravenous fluid the hospital had been administering to him was tainted. Had Fairchild recovered, no doubt he would have set to work immediately designing quality control improvements for intravenous fluid manufacturers. But on March 28, 1971, finally faced with a problem he couldn't solve, Sherman Fairchild died at age 74.

From Canyon to Cosmos

In Great Mambo Chicken and the Transhuman Condition *(published in September by Addison-Wesley), author Ed Regis profiles people involved in "science slightly over the edge." The following excerpt, from the chapter entitled "Truax," picks up after stuntman Evel Knievel's ill-fated 1974 jump over Idaho's Snake River Canyon in the Sky-Cycle X-2, an open-cockpit rocket designed by private launch entrepreneur Bob Truax.*

The X-3 project began when Evel Knievel came up out of the canyon, unharmed except for the cut he got on his nose when he jammed his visor up. Knievel claimed then and forever afterward that he never let go of the stick, and Truax, after inspecting the rocket, agreed, deciding that the parachute mechanism had failed on its own. Anyway, when Knievel climbed up out of the canyon and saw Truax standing there, the first thing he said was, "Well, Bob, that's going to be one hell of a hard act to follow. What else you got up your sleeve?"

Truax had already given the matter some thought. He was impressed by the way Knievel's daredevil acts generated truly massive cash flows. Others were similarly impressed, and soon enough Truax was inundated with all sorts of suggestions for follow-up ventures. A group of Japanese businessmen, for example, wanted to know if Evel Knievel could rocket over Mount Fuji. They even flew Truax over there to assess the matter.

"Technically, it could be done," Truax told them, "but not economically or efficiently." Knievel, though, was always ready: "If Truax says go, I go."

But Evel Knievel would never make an assault on Mount Fuji. Truax had even better things in mind, so when Knievel asked him what they'd do next, Truax's answer was, "Well, if you can scare up about a million dollars, I think I can make you the world's first private astronaut."

It was an altogether reasonable proposition to Knievel, who'd known a few astronauts in his day and already had a hankering to join the club. He gave Truax a small "research grant" of about three thousand dollars to see what he could find out about costs and so forth, but not long afterward Knievel dropped out of the project entirely. He'd gotten into an unfortunate and expensive fray with an associate and no longer had a million dollars for this or any other purpose. But Truax went ahead on his own, for the project appealed to him on several levels. For one thing, launching the world's first private astronaut into space looked to be the ultimate in amateur rocketry. A single individual—he, Bob Truax—would challenge the mighty gods of outer space, and would prevail, with no government help whatsoever, no NASA, no military, no nothing, just his own ingenuity and spare parts. It was a great idea, probably the single best thought he'd ever come up with.

And there could be some money in it too, what with sales of TV and film rights, the book, the magazine articles, all sorts of subsidiary rights, residuals, and God only knew what else. He once asked ICM—International Creative Management, publicists, author's agents, deal maker to the stars—to estimate how much could be brought in from a private astronaut shot. Not much, they said: only $10 million or $20 million.

TINA MION

Then, too, there was another angle, a more serious one. If it was successful, the private astronaut shot could be the *Kitty Hawk* of space travel. It would demonstrate that going into space didn't *have* to be an abnormally expensive undertaking. If a single individual acting on his own could do it, then why not others? Why not private astronaut *corporations*, private *space lines*? The stunt would be a way of getting the Great Space Migration rolling, of getting on with the whole Buck Rogers scenario. Besides, if he could do the shot the way he wanted to—launching it from the water, recovering the vehicle, and then using it again—then he'd exonerate the idea that he'd for a long time regarded as his own personal baby, the *Sea Dragon*.

The *Sea Dragon* was a launch vehicle of stupendous proportions that Truax had designed back when he was director of advanced development at Aerojet General. The best perk of that high office was the $1 million budget that he could spend any way he wanted to. Truax used it to test his pet theory that the *cost* of a rocket had nothing to do with how *big* the rocket was. You could make a given rocket just as big as you pleased and it would cost about the same as one that was about half the size, or even smaller.

This went against conventional wisdom and common sense, but at Aerojet Truax collected enough facts and figures to prove its truth beyond a doubt. Indeed, he'd been assembling the necessary data from the time he was still in the navy, where he'd had access to all sorts of cost information.

* * *

"We came up with a set of ground rules for designing a launch vehicle," Truax said.

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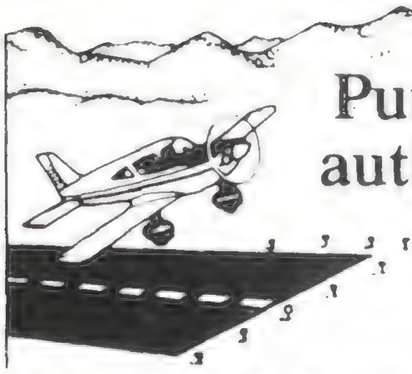

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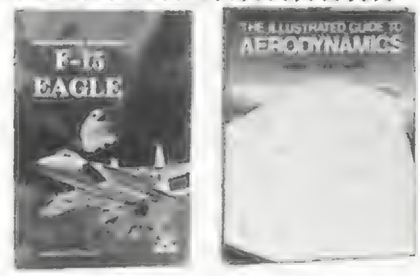

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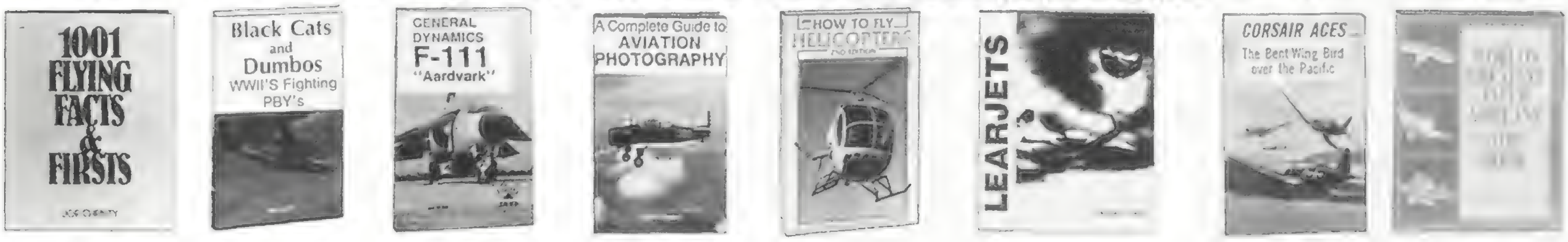

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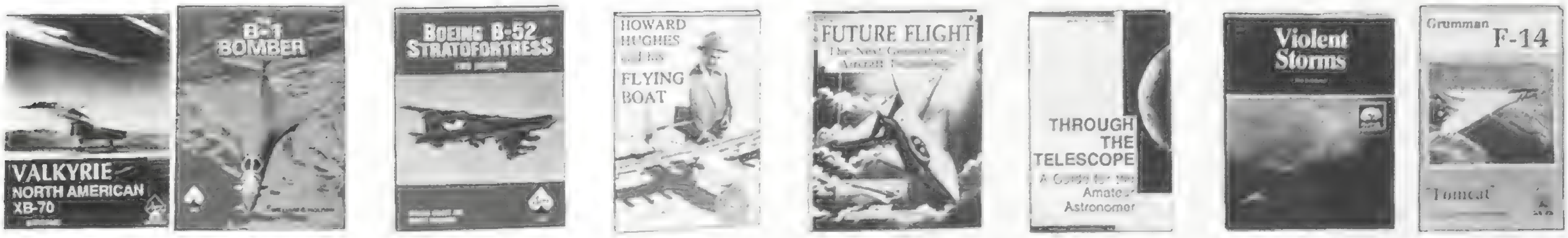

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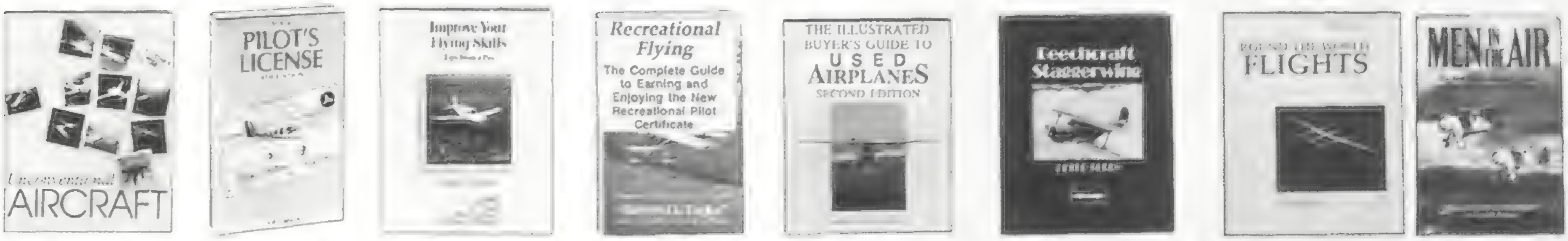

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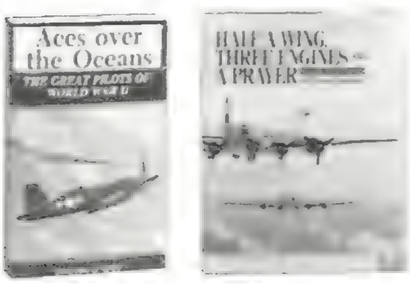

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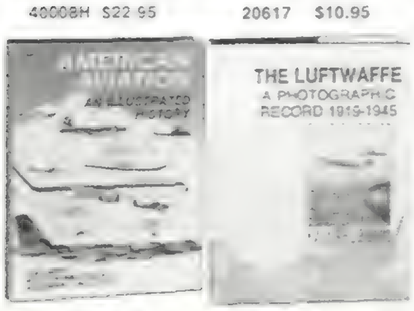

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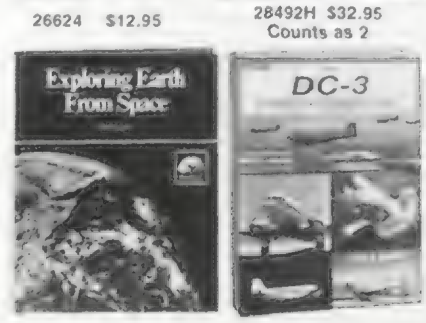

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Bob Truax's *Sea Dragon* was a Big Dumb Booster, an absolutely titanic launch vehicle, one that would weigh forty million pounds at lift-off. The *Saturn V* rocket, by contrast—the one used for the Apollo moon flights, and at that time the biggest rocket ever launched—weighed in at a paltry six million pounds. The *Sea Dragon* would be the *Spruce Goose* of space travel, so big that it would have to be built in a shipyard, and both launched and recovered from the water. After being hauled out from the ocean, the *Sea Dragon* would be refurbished and then sent back up into space. It would be a true "space truck," as opposed to NASA's space shuttle, which was then on the drawing boards.

* * *

Finding volunteer astronauts was a lot easier than finding the cash. For both, Truax placed ads in the *Wall Street Journal*: "Wanted: risky capital for risky project." And: "Man or woman interested in becoming the world's first private astronaut—must be in reasonably good health and able to produce $100,000 in spendable money."

For a long time not much money poured in, but Truax was committed to his project to the point that he mortgaged his house to keep it going. After all, he had plans, drawings, dreams. And he had his surplus rocket parts.

He'd been walking through his favorite rocket-part junkyard in Ontario, California, one time when he spotted some Rocketdyne LR101 vernier engines, *seven* of them. Truax knew all about these engines. They were used for making course corrections on Atlas rockets after main engine shutdown, and to Truax they were works of art. The government had paid millions of dollars to make these things, and there they were, just sitting around rusting. Truax figured he could get them for twenty-five dollars apiece. "For twenty-five bucks," he said to himself, "I'll buy 'em, even if I have to use 'em for paperweights."

So Truax bought 'em. Later he yoked four of them together, to be the motive power behind the X-3, the "Volksrocket."

If surplus parts were easy to come by, so were astronaut candidates. In fact, Truax always had far more astronauts than he ever knew what to do with. There was Martin Yahn, for example, first in a long line, who at the time he volunteered happened to be unemployed and therefore unable to come up with the required $100,000. On top of that he was married and had two children. But he was nuts about going up into space, and whenever Truax rolled his Rocketdyne LR101 vernier engines out for static tests Martin Yahn would be there in his powder-blue jumpsuit marveling at the sights and sounds, enthralled. Truax was so impressed that he put Martin Yahn at the top of the list and decided to send him up for free.

But after a while Martin Yahn vanished into the mists of time, only to be replaced by others . . . . Eventually, astronaut applicants started showing up at Truax's house with some folding money in their pockets. There was "Ramundo," stage manager for the Beach Boys. And there was Daniel J. Correa.

Dan Correa was from Peru. ("He's a bona fide Inca," Truax said.) The son of a mechanic in the Peruvian Air Force, and distantly related to a former president of the country, Correa and his wife arrived in the United States with about $150 between them.

"He heard about the X-3 project in the paper or something," Truax recalled, "and he came around to see me because he thought that his ancestors had come from outer space, and that it was his destiny to go back into outer space. He's a Rosicrucian, and they got some weird ideas."

Correa spoke Spanish and looked Mexican, and anyway he got a job in a tortilla factory rolling out the dough. Because he was always a very gung-ho, extremely ambitious type, he convinced the factory owner to put him out on the road selling tortillas on a commission basis.

Correa sold lots of tortillas, oceans of tortillas, so many you'd never think there were that many tortillas in the whole world, and after a while the owner was paying him off partially in the company's stock. Eventually Correa had acquired so much of the stock that he controlled, and then owned, the company, the Mission Bell Bakery, in Redwood City, California.

Then, right at the apex of his tortilla career, he decided to enter a hitherto unexploited market niche. The average housewife, he realized, had no good way of reheating frozen tortillas. If she put them in a frying pan they got greasy and burned before they were heated all the way through, whereas if she put them in the oven they dried out too fast and got brittle and ended up in a million pieces.

"So I redesigned my baby daughter's vaporizer and came up with this device for rejuvenating the tortilla."

It was Dan Correa's new invention, *The Tortilla Steamer.*

"The Tortilla Advisory Board is pleased with it," he said at the time, "and if I sell 350,000 steamers this year, I will make $5 million, plenty of money for the rocket."

Clearly, Dan Correa was Bob Truax's man. But like the Sky-Cycle X-2, the tortilla steamer concealed a tragic flaw that was

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not apparent at the very beginning. The steamer, which was a small box with a clear plastic top—it looked like a phonograph turntable—was an electrical can of worms. Steam would condense out on the top, drip down the outside, and get into the circuitry where it would cause shorts and make a mess of everything. Unfortunately, before he submitted one of his steamers to the Underwriter's Laboratory for its seal of approval, which it refused, Correa had already manufactured 10,000 units. He then had on his hands 9,999 non-UL-approved tortilla steamers.

What do you do with 9,999 non-UL-approved tortilla steamers? Why, you ship them to Mexico, where consumers are not so uptight about having *seals of approval* on every last item, and you hope to God you can unload them down there.

By this time—it was early 1979—Correa had given Truax a healthy down payment on the rocket flight. "He got to $17,000 or $27,000," Truax recalled, "but then he ran out of money. He lost the bakery, he lost his house, and finally he lost what he had put into the project because he couldn't come through with any more. That was part of the deal, you know: if you didn't get the whole $100,000 then anything you put in was down the drain, because I was spending it as fast as he was putting it in. In

fact I was spending it *faster* than he was putting it in! And so he lost the whole deal."

* * *

When the astronaut position came open again, Truax was besieged with the usual nut-case phone calls. This was his own fault. He'd appeared on "The Tonight Show," and he was telling Johnny Carson and all the rest of the world about the X-3 private astronaut project, and Johnny seemed to love the idea, until Truax suggested that *he* be the victim. "I told Johnny he'd make a good astronaut," Truax said. "But he backed off."

Anyhow, people who wanted to be the World's First Private Astronaut were bugging the hell out of him ("I even had a *blind* guy who wanted to fly it!"), and at length he became a desperate man.

But then one night a San Jose businessman by the name of Fell Peters walked into Truax's garage and asked to go to the top of the list. "Well, it'll cost you $100,000," Truax told him.

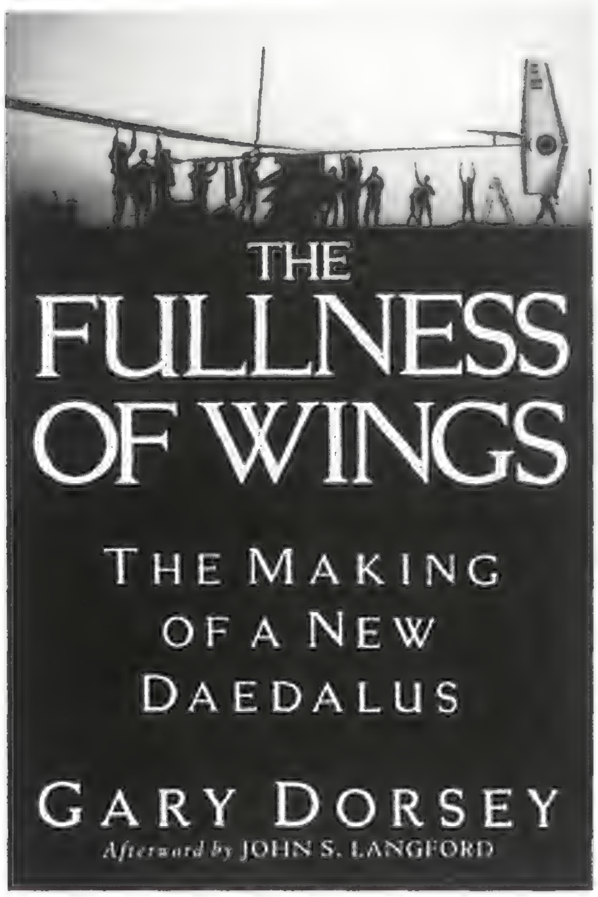
Peters started laying $100 bills on the table, arranging them all into neat piles. Truax, who'd been through this kind of thing time and again (he'd sold the astronaut job four different times by then), expected a few thousand dollars to appear at most. But Peters was still going strong at $20,000. He kept on going even past $30,000.

Finally, the pile reached $40,000. Here, Truax admits, "I weakened." Fell Peters then went to the top of the list.

Later, Truax put Peters through his astronaut training program, which consisted of a ride in Truax's private plane, a Burt Rutan Vari Eze homebuilt. The ride included stalls, steep turns, and other hair-raising maneuvers, all to establish that the astronaut candidate could tolerate high levels of airborne stresses and strains. One of Truax's worst visions was that five seconds into the blast-off, which would be broadcast over live TV, the passenger would start screaming into the microphone, "*Let me out of here!*"

Bob Truax knew as well as anyone else how improbable the whole scheme was (just like the canyon shot had been, for that matter), but still he was utterly serious about private space travel. Sooner or later, he was sure, the X-3 really would lift up into the heavens with a live person aboard. It was no more than a right-thinking man could do with the proper combination of hubris, talent, and spare parts.

"We've got to stop thinking we're helpless," he said. "Hell, we knocked off the moon in ten years."



***The Fullness of Wings: The Making of a New Daedalus** by Gary Dorsey. Viking Press, 1990. 350 pp., b&w photos. $19.95 (hardbound).*

Gary Dorsey tells an occasionally absorbing story in *The Fullness of Wings,* which chronicles the project to build *Daedalus,* an ultralight aircraft that an Olympic bicycle racer pedaled across the Sea of Crete in 1988. Concentrating on the engineers rather than the engineering, the book is at its best when it catches them and their small volunteer workforce against the walls of successive deadlines and shows their scramble to get up and over. To his credit, Dorsey does not paint a pretty picture of these tense times. In fact, he reveals so many petty feuds and resentments and such general time-wasting that the real marvel is not so much the aeronautics that made the flight possible but the fact that the team held together long enough to stage the flight at all.

The book is at its worst when Dorsey transmits without challenge or interpretation the team members' perceptions of the project and themselves. "They had challenged the gods and kings of the modern world, corporate and governmental and scholastic bureaucracies that sought to make money off imaginative aeronautical explorers," Dorsey declaims in the prologue. "They pledged to revise the myth. They would write it anew." This kind of romantic excess is plentiful and gives the book an unintentional mock heroic tone. The guys who built the airplane that flew 74 miles with a bicycle racer at the helm are compared to Apollo program engineers, the Lockheed Skunkworks masterminds, and, of course, Daedalus himself, a character from Greek mythology who escaped King Minos by making himself wings of feathers and wax.

Daedalus was the fifth human-powered airplane to make headlines since 1977. Paul MacCready built the first and probably still most famous ones, the *Gossamer Condor* and *Gossamer Albatross,* which were the first to fly a mile-long figure eight and the first to fly across the English Channel, respectively. Among the competitors MacCready bested in the pursuit of prize money posted by British industrialist Henry Kremer was a group of engineers at the Massachusetts Institute of Technology. That group finally won a Kremer prize in 1984 by building the fastest human-powered aircraft, the *Monarch.* Shortly afterwards they came up with a plan to re-create the Daedalus myth. They spent the next four years building the *Michelob Light Eagle,* a prototype that broke the world distance record, and two versions of *Daedalus.*

According to Dorsey's account, several members of the team, in particular manager John Langford, repeatedly questioned the project's purpose throughout its four years. Although Dorsey explains that Langford and several of the other engineers considered the project an opportunity to advance their careers, he is not altogether satisfied with that motive and adds that they were brought together by "a mutual yearning for creative freedom."

Even if readers skip the author's acknowledgments, the narrative provides plenty of clues to the identity of Dorsey's main source. Langford exerted tyrannical control over the project and appears to have influenced the point of view of the book that was written about it. His decision to keep poor Glenn Tremml, the pilot who broke the distance record in the *Michelob Light Eagle,* from accepting an invitation to a White House dinner, for example, is explained by his rule "that an individual appearance did not suit the image of their quest." Dorsey himself does not question the project leadership. He is instead a superconductor of the main characters' view that MIT, the aerospace industry, corporate America—represented by sponsors United Technologies and Anheuser-Busch—and at times the government of Greece are the imprisoning powers against which the truly creative must rebel.

—Linda Shiner is the senior editor of Air & Space/Smithsonian.

***Beyond the Barrier: The Story of Byrd's First Expedition to Antarctica** by Eugene Rodgers. Naval Institute Press, 1990. 354 pp., b&w photos, $24.95 (hardbound).*

On Christmas day of 1928, en route to Antarctica aboard his expedition flagship *The City of New York,* U.S. polar explorer Richard E. Byrd got his first glimpse of the towering ice shelf that rings the southernmost continent. It was an "awe-inspiring wall," writes Eugene Rodgers, "a sheer cliff of compacted snow higher than the ship." Byrd surmounted that barrier and went on to command history's first flight over the South Pole, erecting a heroic image around himself that has remained inviolate—until now. In *Beyond the Barrier,* Rodgers convincingly dismantles Byrd's carefully cultivated facade.

Rodgers notes that Depression-eve America idolized the 42-year-old Naval lieutenant commander because Byrd "combined four starring parts—aviator,

scientist, explorer, and businessman—into one, and because his sterling character epitomized the true-blue all-American man." In fact, the man who claimed he led the first flight over the North Pole (its success has been disputed) was "a poor pilot and a fumbling navigator," Rodgers discloses, "and he trembled when he flew."

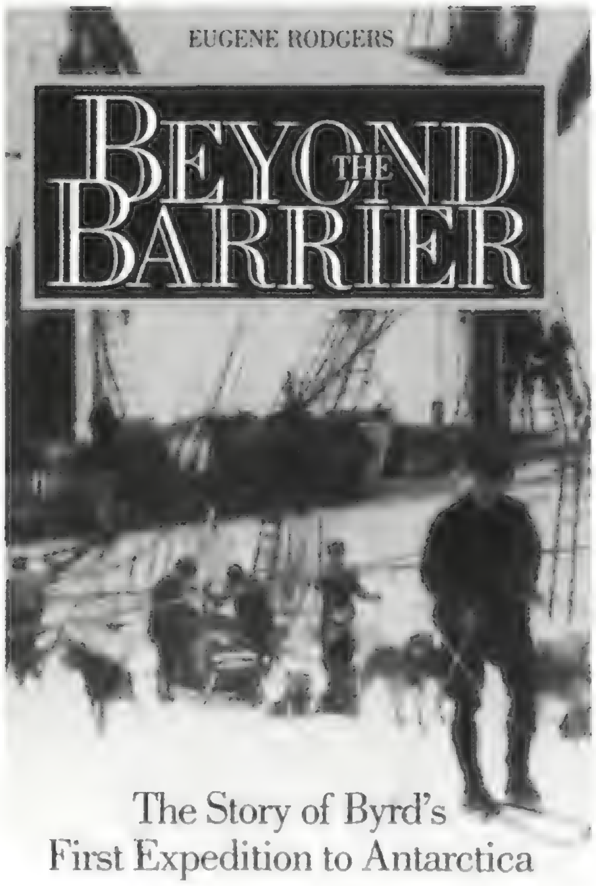
Byrd's fear of flying nearly precipitated disaster during a March 1929 flight to extricate three expedition members stranded on Antarctica's Rockefeller Mountains. According to Dean Smith, pilot of the single-engine Fairchild skiplane that completed the mountain rescue, a hysterical Byrd "leaned over me [during the landing] and began clawing and fighting to reach the controls, his weight forcing my head down and ramming my face into the stick." Only by shoving Byrd back into the cabin, where a third crew member managed to restrain him, was Smith able to touch down safely.

Rodgers also blows the lid off the upright image of life at Byrd's base camp, Little America. Tapping barrels of "medicinal" alcohol, the men made rowdy parties a nightly event. Byrd encouraged—and at times even took part in—the revelry; during one bacchanal, recalled meteorologist Henry Harrison, the commander paraded through the mess hall "rigged up as a perfect dollar waterfront whore." On another bibulous occasion, as Byrd's executive officer, Laurence Gould, helped carry a drunken Byrd back to his bunk, the leader implored, "Above all, don't tell Igloo." Igloo was Byrd's black-and-white terrier.

Beyond the Barrier is no one-sided debunking of the Byrd legend, however. The author takes pains to point out that Byrd was a consummate administrator and fundraiser, a peerless judge of character, and a leader whose devotion to his men drove him to plunge into the icy water of the Ross Sea to save a drowning aircraft mechanic.

Byrd proved especially astute in choosing pilots who were equal to Antarctica's harsh conditions (the explorer himself did not pilot his most famous missions). The region's snowy and crevassed landing sites were often shrouded beneath a drifting ground fog called "sea smoke," and the quirky light could trick fliers into "landing fifty feet up." The pilots also had to contend with crude equipment: on a test flight in the all-metal Ford Tri-Motor that would fly over the South Pole, for example, copilot Harold June patched a leaky fuel pump with a wad of chewing gum.

During the historic flight itself, on November 28, 1929, pilot Bernt Balchen resorted to even more extreme measures.



Trying to fly over a 10,000-foot glacier pass that led to the polar plateau, Balchen ordered Byrd and his two other passengers to jettison every bit of extraneous cargo, including 250 pounds of emergency rations. "The plane shot up a few hundred feet," recounts Rodgers, "but not quite enough to clear the mountain. The Ford was bucking violently in the downdraft spilling off the plateau. Balchen figured there might be a backlash of rising air along the cliff wall to the right. He swung over that way, the wing tip almost touching the rock face. The pole was forgotten—staying alive was all that mattered to anyone."

Balchen found his updraft, and Byrd found not only the pole but a secure niche in the annals of aviation: among the accolades he received for the record-setting flight was the Smithsonian Institution's rarely awarded Langley Medal for aeronautics.

—Allan Fallow is an editorial director in the children's publishing division of Time-Life books.

***The Grand Tour: Exploring the Planets**, Aviation Week Video (1-800-345-8112). Produced by Chedd-Angier Production Co., 1990. Approximately one hour; $49.95.*

I like to imagine great astronomers from the past—Galileo Galilei, William Herschel, Giovanni Cassini, even Percival Lowell—all gathered together in a room to watch footage from unmanned planetary probes. I'd like to see their faces when they first

see close-up images of those planets their instruments could never bring quite close enough. I'd like to hear the sounds of jaws hitting the floor.

If I had only an hour to impress these men, I would probably show them *The Grand Tour.* Though its 60 minutes proves scant time for a thorough tour of the nine planets around our sun (and comets too), this video is a good primer on the scientific results of unmanned solar system exploration. Starting with Mariner 2, which discovered that Venus wouldn't even be a nice place to visit, much less to live, the video covers results from the Mariners, Vikings, Voyagers, and Veneras that taught us so much of what we know about our greater neighborhood.

Some of the footage is stunning (like the incredible computer graphics that portray a trip over the Martian surface), and the talking heads are generally interesting (though once again Venus is said to have "a surface temperature hot enough to melt lead"—isn't it time we compared it to something else?). Factoids are entertaining; Saturn's density, for instance, is so low the planet could float in water. And the information about future missions, such as the Mars Rover and CRAF, the Comet Rendezvous Asteroid Flyby (see "To Spear a Comet," August/September 1990), is quite up-to-date and informative.

Some viewers may find the two military contractor commercials in the tape obtrusive (if I'd paid $49.95 for it I know I

would), and anyone looking for an in-depth study of solar system exploration will feel shortchanged. I just wonder what Galileo would think.

—Tom Huntington is the managing editor of Air & Space/Smithsonian.

National Air and Space Museum 1991 Calendar. Distributed by Random House, $8.95.

With its reproductions of 12 vintage airline posters (the entry for October appears at left), this wall calendar celebrates the days when commercial air travel—and its advertising—were still glamorous.

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The Satellite Sky *shows how Sputnik invigorated American enterprise, both great and small.*

Lindbergh and The Satellite Sky. *Episodes of "The American Experience" on PBS. To air at 9:00 p.m. EST on October 1 (Lindbergh) and November 5 (The Satellite Sky); check local listings.*

For its third season, the PBS series "The American Experience" offers two episodes on flight-related topics. While differing widely in subject and approach, both are well worth an hour in front of the television.

The season kicks off with Steven Ives' *Lindbergh,* a warts-and-all documentary about the young airmail pilot who captured the hearts and minds of the United States with his 1927 solo flight from New York to Paris. Intelligent and well crafted, *Lindbergh* manages to present the various sides, good and bad, of a private man forced to live a very public life.

They called him the Lone Eagle. "I think that's quite American, actually, to do things alone," says Lindbergh's widow, Anne Morrow Lindbergh, and no doubt that very American-ness had a lot to do with his rapturous reception in 1927. It also helped that people saw him as "a darn nice boy," in the words of one radio broadcaster. But *Lindbergh* doesn't flinch from showing its subject's failings—his apparent racism and anti-Semitism; the way he allowed himself, whether unwittingly or not, to be manipulated by Nazi Germany in the years before World War II. He also suffered personal tragedy: his first child was kidnapped and killed, a story given intense scrutiny by the press of the day. *Lindbergh* is an often melancholy tale, but as narrator Stacy Keach points out, today "most people remember only the hero."

Where *Lindbergh*'s approach is straightforward documentary, *The Satellite Sky* is a non-narrative mosaic of footage that shows how the United States reacted to the Soviet Union's 1957 launch of Sputnik 1. Produced by Robert Stone, the show uses science fiction film clips, news footage, commercials, and other found artifacts to paint an impressionistic picture of reaction to "the Space Race." The selections include an advertisement for Soviet-made Laika cigarettes (named after the dog aboard Sputnik 2) and John Glenn's appearance on "Name That Tune," as well as clips of politicians doing what they do best—talking. And for those with a more destructive bent, there's plenty of footage of exploding U.S. rockets. But rest assured: by the end American astronauts are romping on the moon.

—Tom Huntington

Point of No Return: An Aviator's Story by Ralph E. Piper. Iowa State University Press, 1990. 222 pp., $24.95 (hardbound).

Everyone who has been to war—any war—comes home with a story to tell. And he will tell it—reluctantly, openly, over a bottle of wine, in a novel or a memoir. For, like murder, war will out. Though telling a war tale and telling it well is full of difficulties, the best at it make it seem easy.

Such, alas, is not the case with Ralph E. Piper's *Point of No Return,* which is such a mishmash, such a mélange of oddly personal reminiscences, that it is hard to understand why any but a vanity press would consider publishing it. The opening chapters, in which the author regales us with homely little vignettes about growing up in the cornfields of Iowa with his cousin and his pony, skinnydipping and getting caught, set the tone for most of what follows.

This is not to suggest that Piper has not lived an exciting life or, for that matter, a worthwhile one; undoubtedly he has. The book's problems, unfortunately, lie deeper. The author constantly makes reference to his manhood; nothing wrong with that, except that in 1990 this seems strangely out of place. And there are catalogs and lists—of friends, towns, episodes—that, taken together, make up what we call "experience." Unfortunately, these listings seem merely gratuitous. Why does Piper mention the six or seven men he bunked with during his tour in Burma or the five people who accompanied him on a flight to South America aboard a corporate DC-3? No reason, except that they were there. There is no substantive character development, and worse, almost no historical context.

Take "The War Years," for example. For millions of men and women, World War II was not simply a chapter of their lives but an unforgettable series of events that changed them forever. Yet Piper recounts so much of his experience in terms of what things ultimately mean to *him*—how many hours he had on instruments, his rationale for switching from single- to multi-engine flying, the acute awareness of how many missions he needed before he could return stateside—that any historical perspective seems irrelevant, or at least unimportant.

The author explains in his introduction that the title is a reference to those crossroads in life where, once a commitment is made, there is no turning back. "The point of no return can be found in this story of my career. It occurred when I finally knew where I wanted to go," he writes. When he came to authorship, however, turning back may have been wise.

—Douglas McCreary Greenwood has been a licensed pilot since the age of 17.

***Final Approach** by John J. Nance. Crown Publishers, Inc., 1990. 432 pp., $19.95 (hardbound).*

In his first novel, aviation safety expert, lawyer, and former airline pilot John J. Nance stirs into his plot virtually every safety issue in modern commercial aviation, including cockpit resource management, aging airliners, and the pressures of maintaining a good on-time departure record. Add in an unseemly mix of white supremacists, Star Wars technology, and a few token romances, and this tale of an airliner disaster could easily have been a literary disaster.

It isn't. Once past the opening scenes, with their clumsy characterizations and heavy-handed foreshadowing of disaster, the tale quickly gains momentum. The story begins on a stormy night at a Midwestern airport when an airliner attempting to land plows into another waiting on a runway, killing scores of people. Summoned to the scene, National Transportation Safety Board investigator Joe Wallingford soon uncovers some ominous questions as he attempts to bypass roadblocks set in the way of his hunt for the accident's cause—if it was an accident.

Nance's knowledge of the subject stands him in good stead. Dialogue is believable and scenes that could have been stultifying—a NTSB inquiry and a congressional hearing—are instead among the book's most riveting. Although Nance characterizes his unconventional hero—the NTSB investigator—in an utterly conventional way and uses the story as a soapbox to discuss how *he'd* change the system, the result is still a tale of suspense that is both thoughtful and satisfying.

—Karen Jensen edits Reviews & Previews for Air & Space/Smithsonian.

Credits

Broken Arrow. Curt Newport's interest in the Savannah Broken Arrow stems from his experience in underwater salvage operations, including those undertaken for Air India flight 182 and the space shuttle *Challenger.* He is currently employed as a telerobotics specialist.

The Blackbird's Wake. Eliot Marshall is a writer for the News and Comment section of *Science* magazine. His article "Space Stations in Lobbyland" appeared in the December 1988/January 1989 issue of *Air & Space/Smithsonian.*

The Mars Transit System. A U.S. Air Force fighter pilot in the Korean War, Buzz Aldrin earned a doctorate in astronautics from the Massachusetts Institute of Technology before joining NASA as an astronaut in 1964. On July 20, 1969, he and crewmate Neil Armstrong became the first humans to set foot on another celestial body. Now retired from NASA, he lectures throughout the world on America's future in space.

Treasures of the Air and Space Museum. Tom Huntington is the managing editor of *Air & Space/Smithsonian.*

Shuttle Pit Stop. Greg Freiherr is a contributing editor of *Air & Space/Smithsonian.* His article "Invasion of the Spacebots" appeared in the February/March 1990 issue.

The Eyes of England. Historian Alfred Price served in the Royal Air Force and authored *Instruments of Darkness* (McDonald and Jane's, 1977), the definitive history of electronic warfare and its use during World War II. He is also the author of "The Postmodern Bomber," this issue's Flights & Fancy.

Further reading: *A Race on the Edge of Time: Radar—The Decisive Weapon of World War II,* David E. Fisher, Paragon House, 1988.

Sherman Fairchild Looks at the World. Freelance writer Anthony Brandt has been published in *Esquire, GQ, American Heritage, Connoisseur,* and *Psychology Today.* He worked eight years as a Fairchild corporate historian.

Northern Highlights. Elaine de Man is a frequent contributor to *Air & Space/Smithsonian.* Her last article, "Shooting the Stealth," appeared in the August/September 1990 issue.

Calendar

October 5–7
Aviation Art Show and Fighter Aces Symposium. Rare aircraft and radio-controlled model-aircraft exhibit. Champlin Fighter Museum, Mesa, AZ, (602) 830-4540.

October 15–19
International Association of Civil Aviation Chaplains Annual Conference. This year's theme, "Ministering in Our Airports for the 1990s," will focus on dealing with air crashes and accommodating handicapped and immigrant passengers. Simpsonwood Conference and Retreat Center, Norcross, GA, (404) 762-1051.

International Society of Air Safety Investigators Annual Seminar. San Francisco Airport-Marriott Hotel, CA, (415) 592-9707.

October 17 & 18
Advanced Communications Technology Satellite Conference. Sponsored by the National Aeronautics and Space Administration. Las Vegas Hilton, NV, (202) 863-0890.

October 19–21
Kerrville Fly-In. Sponsored by the Experimental Aircraft Association. Aerobatics, aircraft plant tours, and educational forums. Louis Schreiner Field, Kerrville, TX, (512) 896-1155.

Midwest Space Development Conference. Westlake Holiday Inn, Cleveland, OH, (216) 433-5760.

October 23 & 24
"Earth Observations and Global Change Decision Making: A National Partnership." An annual conference sponsored by the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. A discussion of satellite Earth observations. National Press Club, Washington, DC, (313) 994-1200, ext. 3234.

"The Satellite Sky" Update/20

These regular updates to **"The Satellite Sky"** chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2089 8-3-90 PL
- Gamma 1 7-11-90 TT
- Resurs-F7 7-17-90 PL
- Soyuz TM-10 8-1-90 TT
- Titan 4 6-8-90 CAC

300 to 630 MILES

- BADR-1 7-16-90 XI
- Meteor 2-19 6-27-90 PL

630 to 1,250 MILES

- Cosmos 2088 7-29-90 PL
- Cosmos 2090-95 8-8-90 PL

6,200 to 13,700 MILES

- GPS-8 8-2-90 CAC

21,750 to 22,370 MILES

- Cosmos 2085 7-18-90 TT
- Gorizont 20 6-20-90 TT
- Insat 1D 6-12-90 CAC
- Intelsat VI F-4 6-23-90 CAC
- Kopernikus-2 7-24-90 KOU
- TDF-2 7-24-90 KOU

Deletions

90 to 300 MILES

Cosmos 1960 down 4-9-90	Cosmos 2077 down 7-4-90	Resurs-F6 down 6-14-90
Cosmos 2049 down 6-19-90	Cosmos 2078 down 6-28-90	Soyuz TM-9 down 8-9-90

Launched but not in orbit

90 to 300 MILES

Cosmos 2083 USSR photo recon	6-19-90	down 7-3-90
Cosmos 2086 USSR photo recon	7-20-90	down 8-3-90

Inoperative but still in orbit

300 to 630 MILES

Cosmos 1904 Cosmos 1959

Forecast

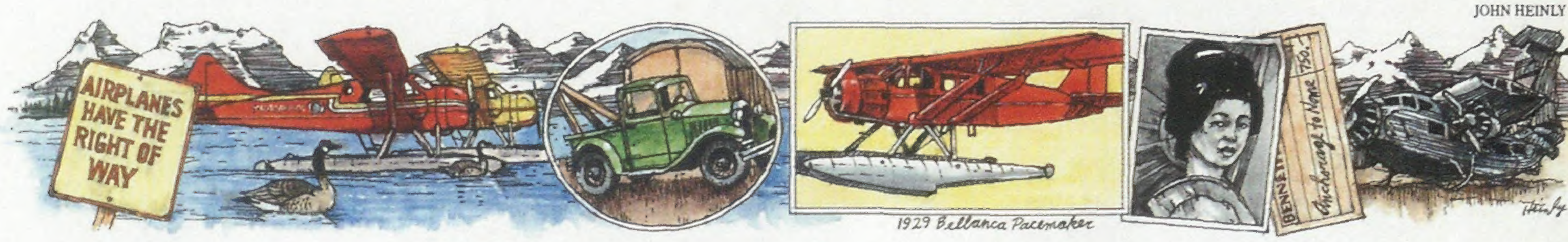
In the Wings . . .

The Soviets' Explosive Mystery. In October 1960 a Soviet rocket blew up on its launch pad, killing as many as 100 people. For years afterwards the West had only a sketchy account of the disaster; now *glasnost* has finally lifted the veil.

Wing Man. He used to be a surrealistic painter. Today John Roncz wrestles on his computer with the realities of airflow. "Without John Roncz," says Dick Rutan, pilot of the round-the-world-without-refueling airplane *Voyager,* "we would have ended up in South America."

Kaman's Copters. Although inventor Charles Kaman knew that helicopters wouldn't really replace the family car, his easy-to-fly designs were still billed as future "air flivvers."

JOHN HEINLY



Northern Highlights

Nearly a thousand floatplanes line the shores of Lake Hood, adjacent to Anchorage International Airport. Canada geese paddle between the pontoons of the Super Cubs, Cessnas, Helio Couriers, and Twin Otters that bob in the water. A de Havilland Beaver with a small fishing boat strapped to a strut slowly accelerates down the canal connecting Lakes Hood and Spenard and eventually lifts off. A sign next to the road that circles the world's busiest floatplane base reminds Gray Line bus drivers that airplanes have the right of way.

Aviation has held Alaska together since 1924, when Carl Ben Eielson, a Fairbanks high school teacher, convinced the U.S. Post Office to send him a mail contract and a de Havilland DH-4. Eielson made his first delivery in the dead of winter, handing the mail over to the citizens of McGrath, 280 miles southwest, three weeks sooner than they would have received it by dogsled.

Eielson was joined by a group of men whose exploits soon became part of Alaskan history—Russell Merrill, Noel Wien, Joe Crosson, Harold Gillam, Bob Reeve. They flew airplanes patched with bedsheets, mended pontoons with flattened gas cans, and landed on glaciers, sandbars, and runways hacked out of mountainsides. But by the late 1970s their legends were beginning to fade.

Ted Spencer wants to keep the legends alive. "I felt like we were running a race," says Spencer, director of the Alaska Aviation Heritage Museum. "Every time I read an obituary I got another surge of adrenaline."

Spencer sits at a cluttered desk on the second floor of the museum, which is located between two busy bush flying services on the southern shore of Lake Hood. A huge yellow and orange Fairchild C-123J Provider with peeling paint is parked on the front lawn. Spencer's office overlooks the lake and the museum's hangar, where Don Robinson is restoring a 1942 Stinson AT-19 Reliant that will wear the markings of Alaska Airlines. The hangar also houses the jewel of the collection, a 1936 Stinson tri-motor.

The museum's emphasis is on civilian aviation up to the 1950s. But, between the roar of floatplanes taking off, Spencer explains that the collection is rooted in his interest in the carcasses of World War II aircraft scattered across the state.

In the late 1970s Spencer founded the Alaskan Historical Aircraft Society to locate, identify, retrieve, and preserve these "icons of Alaskan history," which were disappearing at the hands of vandals, souvenir hunters, and salvagers. At the same time he began to amass artifacts, including what was left of an ex-military PBY-5A Catalina that had been abandoned 30 years earlier on the shore of Dago Lake on the Alaska Peninsula. But for a decade Spencer had no place to display anything.

"We were in the middle of this huge depression," he says. "The price of oil plummeted and people were bailing out of Alaska by the thousands." Nevertheless, in 1987 Spencer signed a lease on a building with broken windows and a hangar with a leaky roof. He convinced a few citizens with historic airplanes to loan them for display, had the Alaska Army National Guard haul in the PBY as a training exercise, and opened his museum in July 1988. Some 7,500 people visited during the first two months.

Today the museum receives about 30,000 visitors a year. They enter through a gallery that displays 120 photos of Alaska's aviation pioneers. Under the picture of Noel Wien, a page from his logbook reveals that between looking for lost airplanes and hauling passengers and freight in the spring of 1928, the sober "dean of Alaskan aviation" took his Stinson Detroiter out for a few joyrides. The smiling face of Joe Crosson belies the tragedies he witnessed: in 1935 he ferried the bodies of Will Rogers and Wiley Post to Fairbanks after their Lockheed crashed following takeoff from Walakpa. And it was Crosson who, during the winter of 1929-1930, led the desperate search in an open-cockpit biplane for his friend Ben Eielson and mechanic Earl Borland, who had disappeared while trying to salvage furs from an icebound trading ship on Siberia's North Cape.

A haunting film about the rescue attempt, narrated by Bob Gleason, the ship's radio navigator and Spencer's uncle, is shown in the museum's modest theater. Also shown are documentaries on World War II in the Aleutians, the retrieval of the museum's PBY, and Alaska's bush pilot heritage.

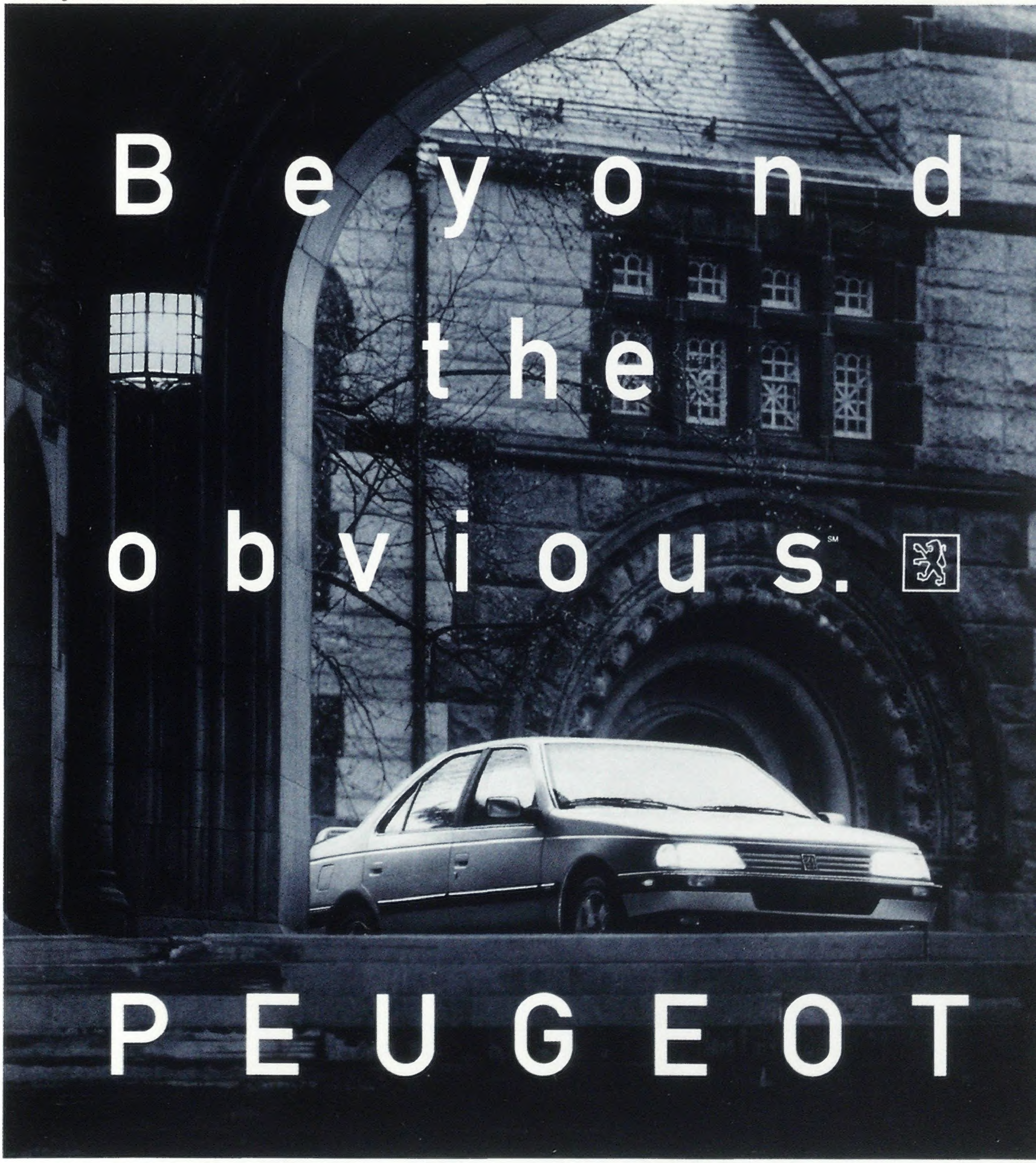
A display case houses a poignant artifact of early Alaskan aviation—a firepot, the open-flame stove used to heat up (and sometimes burn up) frigid engines in winter. On a wall a schedule for Bennett-Rodebaugh, one of Alaska's first airlines, lists the 1928 fare from Anchorage across the state to Nome: $750. Freight flew for a dollar a pound, but furs and gold dust cost twice that. A single case offers a glimpse of the war in the Aleutians, including a photograph of a young woman that was taken from a dead Japanese soldier.

The museum's yard is a mix of beautiful airplanes—such as the 1934 Waco YKC cabin biplane and a Pilgrim Model 100-A monoplane—and twisted wrecks that tell their own story. The pile of corrugated metal with the faint markings of Ptarmigan Airlines is all that's left of Alaska's first Ford Tri-Motor, which arrived in 1934. One year later it ground-looped at a mining town called Flat, where miners used it as a toolshed until someone bulldozed it off a hillside. And the balled-up Bellanca Pacemaker crashed in 1947 when the pilot, ferrying two trappers northwest over the Alaska Range to their trap lines, flew up a false pass in the labyrinthine Rainy Pass and couldn't turn around.

Alaska still holds perils for fliers. A single recent issue of the *Anchorage Daily News* reported three airplane accidents. Still, the north continues to lure aviators. "Alaska," Noel Wien said, "keeps a fellow guessing .... It tugs at you all the time."

—Elaine de Man

Alaska Aviation Heritage Museum, 4721 Aircraft Drive, Anchorage, AK 99052. Tel. (907) 248-5325. Open Monday through Saturday, 9 a.m. to 6 p.m.; Sunday, noon to 6 p.m. Admission: $5 adults, $2.50 children under 12.



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